SITE SELECTION PROCESS - PHASE 4A

TECHNICAL APPENDIX LF-3C

GEOLOGIC HYDROGEOLOGIC, AND

GEOTECHNICAL CONSIDERATIONS

REPORT PREPARED FOR
THE ONTARIO WASTE MANAGEMENT CORPORATION
BY
GARTNER LEE ASSOCIATES LIMITED

THIS REPORT IS ONE OF EIGHT TECHNICAL APPENDICES DESCRIBING GEOLOGIC, HYDROGEOLOGIC AND GEOTECHNICAL CONSIDERATIONS OF THE CANDIDATE SITES. IT SUPPORTS THE COMPARATIVE EVALUATION STUDY WHICH IS ENTITLED "SITE SELECTION PROCESS; PHASE 4A, SELECTION OF PREFERRED SITE(S), GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS".

AUGUST, 1985

PROJECT 85-S18.3

Gartner Lee
Associates Limited

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August 28, 1985.

Dr. B.D. Mitchell, Director,
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Ontario Waste Management Corporation,
2 Bloor Street West,
11th Floor,
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Attention: Mr. J.G. Micak,
Manager,
Environmental Projects

Dear Dr. Mitchell:

Re: Site Selection Process - Phase 4A
Technical Appendix LF-3C - Geologic, Hydrogeologic,
and Geotechnical Considerations

Enclosed is our final report on the Geologic, Hydrogeologic, and Geotechnical Considerations at Candidate Site LF-3C. Similar reports prepared for each of the other candidate sites will form the basis for site comparisons.

Thank you for allowing our company to be of service. If clarifications are required please contact our office.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

Stuart Anderson

E.G. Anderson, P.Eng.
Project Director.

KJG:jcm
Enclosures.

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STUDY TEAM

This report was prepared under the overall direction of Grant Anderson, P.Eng., Project Director and Gunther Funk, Project Manager. Major contributing authors were:

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Field Coordination	Norbert Woerns

1.0 INTRODUCTION

1.1 BACKGROUND

The Ontario Waste Management Corporation's (OWMC) site selection process to locate facilities for treating hazardous wastes and disposing of the treated waste residues has been a phased process which began in 1981. Initial studies identified 261 hydrogeologic areas throughout southern Ontario which were grouped into six zones. Within the Golden Horseshoe, Zone 1 and 2 lands were considered most favourable for facility siting. Twenty candidate areas were identified within the zone 1 and 2 lands in the Golden Horseshoe in 1983. A total of 152 sites were identified in these twenty candidate areas in 1984 and this number was subsequently reduced in stages to sixteen potential sites and finally to eight candidate sites through the application of various constraints, screening processes, and ranking systems based on multidisciplinary factors. A more complete discussion of the site selection process is provided in "Site Selection Process; Phase 4A, Selection of Preferred Site(s): Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

The present stage of study is the comparative assessment of the eight candidate sites. This Gartner Lee Associates Limited (GLAL) report documents and interprets available geologic, hydrogeologic, and geotechnical information for Site LF-3C and serves as the data source for input to the comparison study. The candidacy of this site is based on the potential development of a total treatment facility including a landfill. The Phase 3B preliminary assessment of this site was based

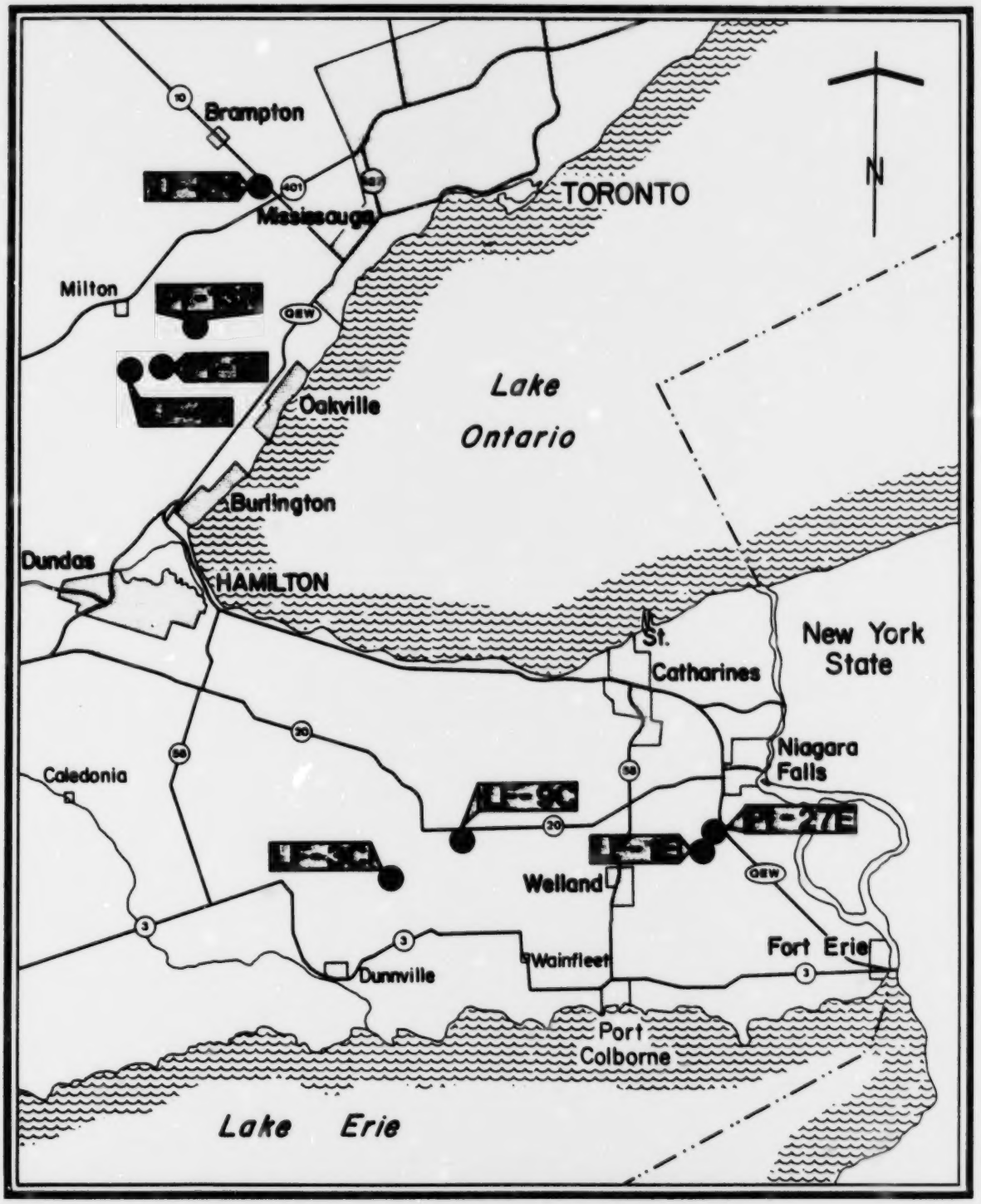


FIGURE 1 LOCATION OF CANDIDATE SITES

primarily on existing data (Gartner Lee Associates Limited 1984b). Phase 4A investigations described in this report add significantly to the geologic, hydrogeologic, and geotechnical data base.

1.2 OBJECTIVES AND SCOPE

The objectives of this report are to provide data for Site LF-3C to accomodate comparison with the other siting options. These objectives have been met through additional investigations. The existing data base has been upgraded where possible and five boreholes have been drilled at selected locations on the site. Each of the boreholes has been continuously sampled to provide detailed geologic logs and soil samples for future reference. Boreholes were not instrumented and were plugged using grout on completion.

1.3 LOCATION

Site LF-3C is located in the central portion of the Niagara Peninsula roughly midway between Hamilton and Fort Erie. It is shown together with the seven other candidate sites in Figure 1 and is presented in greater detail in the figures in the map pocket at the rear of the report.

The site under consideration in this Technical Appendix covers approximately 259 hectares and includes Lots 5, 6, and 7, Concession 1 in West Lincoln Township (previously Gainsborough Township), in the Regional Municipality of Niagara. It is bounded on the west by Regional Road 16, on the north by Elcho Road West and on the south by Zumstein Road. The site is approxmately 25 km southwest of St. Catharines, 40 km south-

east of Hamilton and is roughly centred in a study area of about 2600 ha. It is about 3.0 km west and north of Wellandport and 0.8 km northwest of the Welland River at its closest point.

2.0 METHODOLOGY

The methodology employed in the collection, compilation, and interpretation of the information base presented in this technical appendix report is described below and illustrated in Figure 2.

2.1 DATA COLLECTION

The following sources of information were used:

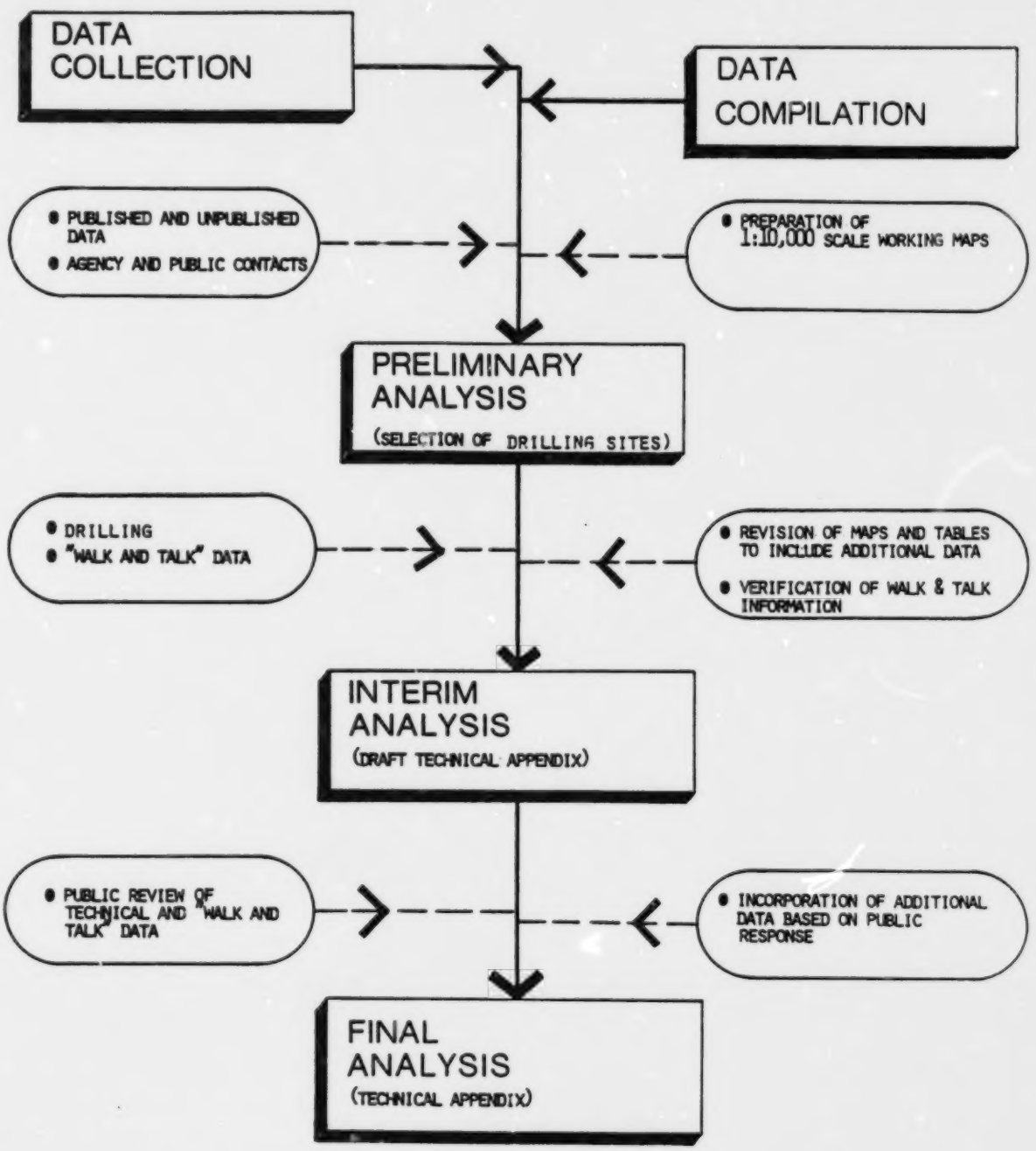
- water well and borehole records; published and unpublished reports, maps and 'open file' reports;
- interviews with government agency personnel and local residents; and
- onsite drilling and field survey results.

2.1.1 DATA BASE:

Numerous reports and maps which contain both regional and local information on the geology and hydrogeology of the candidate sites were assembled during the earlier phases of the site selection process. Reports specific to this site are referenced in the text and are listed in Section 7.0.

Figure 2

Methodology Flow Chart


DATA COLLECTION
DATA COMPILATION
• PUBLISHED AND UNPUBLISHED DATA
• AGENCY AND PUBLIC CONTACTS
• PREPARATION OF 1:10,000 SCALE WORKING MAPS
PRELIMINARY ANALYSIS
(SELECTION OF DRILLING SITES)
• DRILLING
• "WALK AND TALK" DATA
• REVISION OF MAPS AND TABLES TO INCLUDE ADDITIONAL DATA
• VERIFICATION OF WALK & TALK INFORMATION
INTERIM ANALYSIS
(DRAFT TECHNICAL APPENDIX)
• PUBLIC REVIEW OF TECHNICAL AND "WALK AND TALK" DATA
• INCORPORATION OF ADDITIONAL DATA BASED ON PUBLIC RESPONSE
FINAL ANALYSIS
(TECHNICAL APPENDIX)

Supplementary information was collected during meetings with government agency personnel. This information included:

- copies of original water well records obtained from the Ministry of the Environment, and

- copies of oil and gas well records obtained from the Ministry of Natural Resources.

The water well and oil and gas well records are summarized and presented in Sections 8.1 and 8.2. Copies of the data are on file.

2.1.2 INTERVIEWS

Additional information regarding site geology and water use was obtained during interviews with government agency personnel and local residents. The results of the interviews are PRE-sented in the summaries prepared for agency meetings (by GLAL) and on resident interview forms (prepared by Ecologistics Limited). Meetings were held with the local public interest group made up of residents and other interested individuals. The group identified items of geologic and hydrogeologic interest. The summaries of meetings and the interview forms are on file. Local water use information summarized from the interview forms is tabulated in Section 8.3.

2.1.3 DRILLING AND FIELD SURVEY RESULTS:

Borehole locations were selected based on preliminary analyses of available data and input from the public. Five boreholes were completed at selected locations on site to investigate the expected character and continuity of the geologic materials. Drilling and sampling procedures are presented in

the document entitled "Phase 4A Drilling and Sampling Activities and Protocol" (GLAL 1984a) and the detailed methods employed during this study are summarized in Section 8.8.

The drilling program involved the collection of continuous samples from boreholes. These samples were photographed and described in the field, placed in suitable containers, and shipped to the Ontario Geological Survey in Toronto for storage. Split spoon samples were taken at 1.5 m intervals to obtain standard penetration resistance values and samples for moisture content determinations in order to make preliminary comments on geotechnical aspects. Detailed borehole logs were prepared based on the field descriptions and on subsequent re-examination of the samples in storage. These logs are presented as part of the supporting information package in Section 8.4.

Test pits and hand-auger holes were also dug on the site and on adjacent properties. Some of this work was carried out by local residents and other work was carried out by GLAL field staff at their request to answer questions and concerns regarding shallow geologic conditions. Each location investigated has been classed as a 'field station' and descriptions of each field station are provided in Section 8.4.

2.2 DATA COMPILATION AND ANALYSIS

Data compilation and analysis has proceeded in a staged fashion which is depicted in Figure 2. In the initial work, data (such as water well information) were compiled on summary tables and illustrated on a series of working maps and cross-sections at a scale of 1:10 000. Maps included plots of:

- data point locations (all sources);
- geology (Ontario Geological Survey reports, constraint mapping results from Phase 3B, and Ministry of the Environment maps and reports;
- bedrock elevations (water well and oil and gas well data) data);
- confining layer thickness (water well data);
- aquifer thickness (water well data);
- aquifer information (water well data); and
- anomalies such as granular zones (water well data).

These maps were used to establish the geographic distribution of existing data points and to confirm at a more detailed scale the preliminary interpretation of geologic and hydrogeologic conditions as presented in Phase 3B documentation (Gartner Lee Associates Limited 1984b). Tentative drilling locations were then identified based on these preliminary analyses.

Following the selection of the tentative drilling locations, GLAL personnel met with interested parties to present the results of the preliminary analysis and to discuss the purpose and scope of the Phase 4A program. Additional information on geologic and hydrogeologic conditions was collected during these meetings. Landowners and tenants were contacted at this time to obtain permission to drill on their properties and drill site locations were modified based on local inputs.

A separate data collection program commonly referred to as the "Walk and Talk" survey was also undertaken. During this survey, individual residents were interviewed by personnel from

Ecologistics Limited and the results were presented in a questionnaire format. Among the multidisciplinary questions were several which were provided by Gartner Lee Associates Limited and which related specifically to water supply and use. The collection of ground water information and related water use data was limited primarily to the site and to adjacent properties.

With the completion of the drilling and public survey programs, the working maps were revised to incorporate the additional information that was collected. This technical appendix presents the interpretation of geologic, hydrogeologic, and geotechnical conditions at LF-3C to date. Draft copies of the data summaries were circulated to the local interest group as a check for completeness and accuracy.

3.0 REGIONAL GEOLOGY AND HYDROGEOLOGY

The geology and hydrogeology of the Niagara Peninsula are summarized and discussed in reports prepared for the Ontario Waste Management Corporation (Gartner Lee Associates Limited 1984b,c). This section is based on these reports and the reader is referred to them for more detail and for a complete list of references on which they are based.

3.1 REGIONAL GEOLOGY

3.1.1 BEDROCK GEOLOGY AND OVERBURDEN THICKNESS

Bedrock in the Niagara Peninsula consists of a sequence of

sedimentary formations which dip slightly to the south. This southerly dip exposes the various formations on the buried bedrock surface in east-west trending bands. Figure 3 shows the approximate location of Site LF-3C on a generalized cross-section of the Peninsula and names the major geologic units. The site is located over a bedrock depression of regional dimensions between the Niagara and Onondaga escarpments near the contact of the Guelph and Salina formations. Depths to bedrock in the vicinity of the site are generally in the 20 to 30 m range.

3.1.2 QUATERNARY GEOLOGIC HISTORY

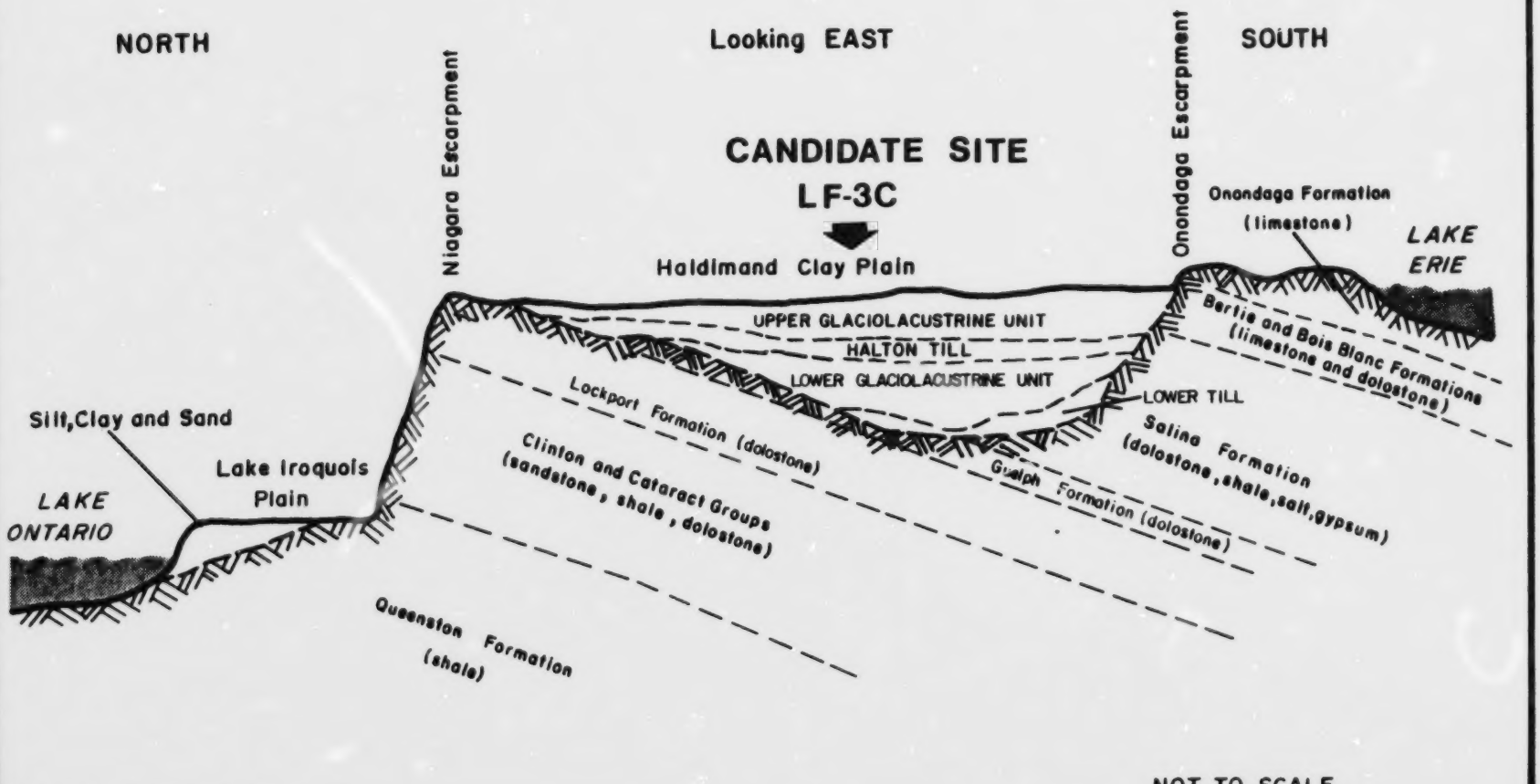
Regional overburden units are indicated in Figure 3. From oldest to youngest they are, (1) a lower till directly over the bedrock, (2) a lower glaciolacustrine unit, (3) an upper till (Halton), and (4) an upper glaciolacustrine unit. The geologic sequence of events associated with these deposits began with a major ice advance which deposited the lower till over the Niagara Peninsula. This advance occurred approximately 23 000 years ago and the ice remained there until it withdrew northward approximately 14 000 years ago. Deposition of the lower glaciolacustrine unit occurred in a subsequent glacial lake. A brief readvance of the ice into the glacial lake resulted in the deposition of the Halton Till about 13 000 to 12 000 years ago. As the Halton ice withdrew, the lake re-formed in front of it and the upper glaciolacustrine unit was deposited. Following drainage of this lake, the upper glaciolacustrine deposits have been subjected to weathering and erosion to produce the present landscape.

3.1.3 QUATERNARY GEOLOGY:

Generalized descriptions of each of the major overburden units are presented to provide a regional perspective on their char-

FIGURE 3

Cross-Section Sketch Through The Eastern Niagara Peninsula



Reference: Adapted from GLAL 1984c

NOT TO SCALE

Gartner Lee Associates Limited

acteristics and distribution. These are also used to place the discussionn of the site geology into context.

A sandy silt to silty sand till occurs above the bedrock at scattered locations throughout the Niagara Peninsula (Feenstra 1974, 1975, 1981, Barnett 1975) and it is generally acknowledged to be the Wentworth Till. This unit is also referred to in the literature as the "lower till" and this term is used here. The lower till is encountered in all five onsite boreholes and is inferred in more than half the water well logs in the vicinity where it is identified as "clay and stones' 'clay and gravel' and 'hardpan'. Sand and gravel deposits between the bedrock and the lower till are reported in numerous water well logs and have been summarized in previous reports (GLAL 1984b,c). Since none of the GLAL boreholes on this site detected similar granular deposits, it is considered that the sands and gravels are discontinuous.

Owen (1969, 1972) and Feenstra (1981) have described a buried lower glaciolacustrine deposit between the lower till and the Halton Till. They note a regional composition which includes clays, silts, and sands and indicate that this layered deposit is often only a few metres thick.

The Halton Till occurs between the upper and lower glaciolacustrine units over most of the Niagara Peninsula. The Halton Till is generally buried beneath upper glaciolacustrine deposits and is not usually exposed at surface. It may outcrop where the upper glaciolacustrine deposit is eroded (in valleys), where the Halton Till thickens in moraines, or where bedrock is exposed. Till composition in the central portion of the Peninsula reflects the silts and clays of the underlying

glaciolacustrine deposits which are incorporated into it. Feenstra (1981) notes that the typically clayey and silty Halton Till deposits are interspersed with sand and silty sand lenses on several moraines in the Niagara Peninsula. Portions of the Halton Till may be waterlain according to Feenstra (1981).

The upper glaciolacustrine unit consists primarily of silts and clays which occur at the surface over a large portion of the Niagara Peninsula and which constitute the Haldimand Clay Plain. Feenstra (1981) describes it as a "massive or stratified (varved in places) silty clay....with generally more than 50% clay and 5% sand". Feenstra (1975) also notes that this unit has been observed up to 16 m thick. Thin lenses and laminae of sand have been observed within the upper 2 m of the upper glaciolacustrine unit at several locations in the region. Glaciolacustrine deposits immediately underlie the site and most of the area in the vicinity. The upper and lower glaciolacustrine units and the Halton Till are considered to comprise the 'clay' deposits which account for most of the overburden materials described in the water well logs (Section 8.1).

Alluvial deposits occur in association with flood plains in the region and are confined laterally and from below by the upper glaciolacustrine unit. They tend to be fine-textured reflecting available source materials and low to moderate stream gradients.

3.2 REGIONAL HYDROGEOLOGY:

The regional distribution of bedrock units is illustrated

in Figure 3. The Salina and Guelph formations are major regional aquifers and their contact roughly underlies the site. The Guelph Formation produces the better yields and the better water quality in the area although the water may locally be mineralized. Water quality in the Salina Formation is generally poor due to the presence of evaporites (primarily gypsum) in the shale sequence. Hydraulic conductivity in both formations is usually best developed as a result of fracturing and enhancement of fractures by solution in the upper few metres of bedrock, immediately below the overburden-bedrock contact.

The lower till is sandy to silty and contains pebbles and cobbles. It may overlie the bedrock directly or it may be locally separated from it by basal granular deposits. The basal granular deposits are occasionally sources of water supply to drilled wells, however the lower till itself is considered not to have water-bearing potential because of its silty texture. Where basal granular deposits occur, they are considered to be in good hydraulic connection with the bedrock.

The upper and lower glaciolacustrine units and the Halton Till comprise a hydrostratigraphic unit of regional extent which is referred to in this report as the confining layer. The confining layer consists primarily of horizontally bedded, laminated clays and silts. Downward hydraulic gradients generally exist across this unit, however ground water flow rates and quantities are very small. Hydraulic conductivities reported in similar materials by Desaulniers et al. (1981) near Wainfleet average approximately 3×10^{-10} m/s and several values in glaciolacustrine deposits near Lewiston, New York were also in the 1×10^{-10} m/s range (Wehran Engineering P.C. 1983). No drilled wells are known to obtain water from the confining layer.

The surficial fractured portion of the confining layer extends to depths which range up to several metres. Occasional dug and bored wells reportedly obtain water supplies from this zone on a local basis. Saturated fracture systems and granular laminations within the lacustrine deposits are considered to be the source of water to such wells. In view of the fine-textured character of these deposits and the limited porosity of the fractures, yields to most shallow dug and bored wells are expected to be low and users likely rely on well-bore storage for periods of peak use. Alluvium may provide water supplies to shallow dug and bored wells at some flood plain locations.

4.0 SITE GEOLOGY AND HYDROGEOLOGY

The discussions of geology and hydrogeology of Site LF-3C take into account the regional data as well as the new GLAL borehole information. In addition, data from hand auger holes, test pits, and formal and informal interviews are integrated into this analysis. Figure 4 (in map pocket) provides locations of field data and indicates locations of cross-sections.

Results from the GLAL borehole program are used to confirm the geology and hydrostratigraphy and to evaluate the predictability and uniformity of subsurface conditions. Hydrogeologic discussions are based on the borehole geology and on such additional sources of information as the water well records and water use data provided by local residents. Table 1 presents local geologic and hydrostratigraphic units for the

site and vicinity. This table provides the framework for the discussions that follow.

4.1 SITE GEOLOGY

Five continuously sampled boreholes were drilled to investigate the subsurface geology. Three of these boreholes were cored into bedrock and two were terminated in the lower till.

TABLE 1: SUMMARY OF LOCAL GEOLOGIC AND HYDROSTRATIGRAPHIC UNITS

GEOLOGIC UNIT		HYDROSTRATIGRAPHIC UNIT	
ALLUVIUM			ALLUVIUM
UPPER GLACIOLACUSTRINE			FRACTURED ZONE (UPPER GLACIOLACUSTRINE)
		CONFINING	
HALTON TILL		LAYER	UPPER GLACIOLACUSTRINE, HALTON TILL, LOWER GLACIOLACUSTRINE
LOWER GLACIOLACUSTRINE			
LOWER TILL			LOWER TILL
BASAL GRANULAR			BASAL GRANULAR AND BEDROCK AQUIFER
BEDROCK (SALINA DOLOMITIC SHALE AND GUELPH DOLOSTONE)			

Note: Alluvium is present along the Welland River Flood Plain and along Beaver Creek.

GLAL borehole locations are shown on Figure 4 along with water wells, oil and gas wells, and field station sites (hand auger holes and test pits). Logs of the GLAL boreholes and summaries of other subsurface data are included in Section 8.0. Cross-sections through the study area are presented in Figures 5 and 6 (in map pocket). The geologic names in the borehole logs (e.g. Halton Till, upper glaciolacustrine unit) are used to relate the local geology to the established regional geologic framework and are based on published descriptions. Geologic descriptions on cross-sections have been simplified for presentation.

4.1.1 TERRAIN

Site LF-3C is located on a portion of the Haldimand Clay Plain (Chapman and Putnam 1966). The plain is generally flat to gently rolling except where it is dissected by stream erosion, however these valleys are relatively minor physiographic features. There are many small, shallow, poorly drained depressions (approximately a metre deep) on the surface of the plain which may contain standing water for much of the year. Elevations (above sea level) on the site range from 175 m along Beaver Creek and along drainage courses along the southern boundary to 180 m in the central portion of the site. Beaver Creek traverses the northern part of the site and an abandoned channel of the Welland River occurs south of the site. Both water courses meander and their floodplains are broad.

4.1.2 BEDROCK GEOLOGY AND DRIFT THICKNESS:

Borehole GL3 encountered grey dolomitic shale with gypsum nodules while Boreholes GL4 and GL5 encountered a light-grey, fine-grained dolostone with occasional vugs. These descriptions are similar to those provided by Telford et al. (1976)

and are considered to indicate the Salina and Guelph formations respectively. Results suggest a slight refinement of the contact between the two formations to pass through the site rather than north of Beaver Creek as it is shown on the published map (Telford et al. 1976). The bedrock surface slopes generally southward across the study area with elevations of about 160 m in the north and 150 m in the south.

Overburden thicknesses in the three GLAL boreholes which reached bedrock are 23.1, 26.0, and 31.4 m. It is reportedly 31.1 m in the single onsite bedrock water well (# 417, Table 4 Section 8.1). This range is in good agreement with the Phase 3B estimate of 24 to 29 m based on water well and borehole records.

4.1.3 BASAL GRANULAR UNIT

Several water wells in the study area reportedly penetrate sands and gravels which occur between the bedrock and deposits which are inferred to be the lower till. They generally range from less than a metre up to 3 m in thickness. Since no comparable deposits were encountered in the GLAL boreholes, they are considered to be discontinuous.

4.1.4 LOWER TILL

A silty sand to clayey sandy silt till was encountered between the bedrock and the lower glaciolacustrine unit in the GLAL boreholes (Figures 5 and 6 in map pocket). At the three locations where the boreholes fully penetrate the overburden, the till occurs directly on the bedrock and ranges in thickness from 0.5 to 5.2 m. It is typically dark greyish brown, very dense, saturated, and shows minor variability in colour and texture between boreholes. Water well logs

generally report 'stony clay', 'clay and gravel' or 'hardpan' between the 'clay' and bedrock and such deposits are inferred to be the lower till.

4.1.5 LOWER GLACIOLACUSTRINE UNIT

This unit ranges in thickness from 1.2 to 4.3 m in the GLAL boreholes and consists generally of laminated silty clay and clayey silt with occasional small pebbles (Section 8.5). Approximately half (2.2 m) of the lower glaciolacustrine unit in Borehole GL1 consists of fine sand. In three of the five GLAL boreholes, the contact with the overlying Halton Till is gradational. In Borehole GL4 interbeds of sandy silt occur in the upper portion of the unit, however these were not encountered in other boreholes.

4.1.6 HALTON TILL

The Halton Till was identified in the five GLAL boreholes and is typically a silty clay to clayey silt with occasional pebbles. It ranges from massive to indistinctly laminated and commonly grades into both underlying and overlying glaciolacustrine units. A 6 cm thick layer of silt to silty fine sand was observed in the till in Borehole GL1. The till varies between 2.5 and 5.5 m in thickness. The laminations and gradational contacts suggest a waterlain origin. This interpretation is consistent with the geologic history of the region proposed by Feenstra (1981).

4.1.7 UPPER GLACIOLACUSTRINE UNIT

This unit is typically brown to dark grey silty clay to clayey silt with occasional small pebbles less than a centimetre in size. It is usually laminated with red and grey layers but may contain massive zones. A subtle colour change

occurs from brown to grey brown or grey between depths of 5 to 7 m. The upper 1.5 m is most heavily weathered and fractured and rarely shows visible laminations. Fracture frequency decreases rapidly with depth and fractures are rare below about 5 m. The deepest evidence of fracturing was noted in Borehole GL5 at a depth of 12.0 m. Grey carbonate infilling (with a clay-like texture) was observed in many fractures. Gypsum and/or calcite crystals up to a centimetre long were also occasionally noted along other fractures.

Occasional silt or fine sand laminations were observed in the samples and in most cases these were 'paper thin' and barely visible. Based on test pit and hand auger logs and the geologic log for Borehole GL5, the surficial portion of the glaciolacustrine unit may contain occasional layers of fine sand or silt up to a centimetre thick. These layers are commonly rusty brown and several observed in the field appeared to be saturated. The upper glaciolacustrine unit ranges in thickness from 15.5 m (Borehole GL2) to 20.0 m (Borehole GL1) and appears to be thickest in the central portion of the site.

4.1.8 ALLUVIUM

Alluvial deposits underlie the abandoned meander of the Welland River which crosses the southernmost portion of the proposed site. Several test pits and auger holes are located on or adjacent to the Welland River flood plain and logs are provided in Section 8.4. Descriptions of the deposits which underlie this area indicate generally silty and clayey conditions with occasional thin granular seams. Offsite investigations in alluvial areas were undertakern primarily at the initiative of local residents.

4.1.9 DISCUSSION

Geologic conditions in the study area and beneath Site LF-3C are considered to be uniform and predictable. Fine-textured deposits, primarily of glaciolacustrine origin, constitute the bulk of the overburden which ranges in thickness from 20 to 26 m on the site. Occurrences of granular deposits are limited to occasional basal sands and gravels (reported in water well records)and to the sandy lower portion of the lower glaciolacustrine unit in one GLAL borehole.

4.2 SITE HYDROGEOLOGY

The Phase 4A geologic field work incorporates first-hand geologic descriptions and interpretations with the existing data bases which consist primarily of the water well record information. Hydrogeologic analyses utilize GLAL borehole geology, water well records, information obtained from the public, information supplied by researchers in similar hydrogeologic settings, and the experience of Gartner Lee Associates Limited staff. Descriptions of the hydrostratigraphic units, flow systems, and ground water use are presented in the following sections.

4.2.1 HYDROSTRATIGRAPHY

Two major hydrostratigraphic units are present at Site LF-3C. These are (1) an aquifer which consists of the upper bedrock and associated granular deposits, and (2) a confining layer which extends from surface to the first significant granular unit or to bedrock. Confining layer thicknesses for the study area and the site are presented in Figure 7 (in map pocket).

4.2.1.1 BEDROCK AND GRANULAR AQUIFER

The bedrock is the most important source of water to drilled

wells in the study area. The fractured upper portion of the bedrock is considered to constitute a permeable zone which is a preferred avenue for lateral ground water flow. The consistency with which adequate water supplies are encountered within the upper few metres suggests that horizontal fracturing is well developed, however the reported ranges in pumping rates and drawdowns suggests that fracture development is variable. The thickness of the fractured zone is considered to be about 5 m and the average hydraulic conductivity is estimated to be $1x10^{-5}$ m/s based on local water well record data and analytical procedures described by Walton (1962) and Ogden (1965). The average porosity is considered to be about 0.01 and the average lateral gradient is estimated to be approximately 0.005 based on reported static water levels in wells. Approximately a third of the well records in the study area report granular materials above the bedrock and water supplies have been developed at about half these locations. The bedrock and adjacent granular deposits are considered to be in good hydraulic connection and ground water flow is considered to occur primarily through the bedrock because of the discontinuous nature of the granular aquifer.

4.2.1.2 Confining Layer

The confining layer extends from the surface to bedrock except at Borehole GL1 where it terminates in fine sand at the base of the lower glaciolacustrine unit. The confining layer is characterized by fine-textured materials which have low hydraulic conductivites. It includes three hydrostratigraphic subunits which are (1) the lower till, (2) the lower glaciolacustrine unit, The Halton Till, and the unfractured upper glaciolacustrine unit, and (3) the fractured surficial portion

of the upper glaciolacustrine unit. Each of these units is discussed and described in the following paragraphs. Table 2 summarizes the thicknesses of each of the confining layer components and selected hydrogeologic properties of each.

TABLE 2: SUMMARY OF CONFINING LAYER CHARACTERISTICS

BOREHOLES / PARAMETERS	THICKNESS OF CONFINING LAYER SUBUNITS			THICKNESS OF CONFINING LAYER
	LOWER TILL (m)	UNFRACTURED GLACIOLACUSTRINE UNITS & HALTON TILL (m)	SURFICIAL FRACTURED ZONE (m)	(m)
GL1	N/A	21.3	5.0	26.3
GL2	4.4+	15.4	5.0	24.8+
GL3	0.5	17.6	5.0	23.1
GL4	1.0	20.0	5.0	26.0
GL5	5.2	21.2	5.0	31.4
AVERAGE HYDRAULIC CONDUCTIVITY m/s	$1x10^{-8}$	$3x10^{-10}$	$1x10^{-8}$	
AVERAGE POROSITY	0.3	0.5	0.0001	

Notes: - N/A - not applicable

- unfractured porosity values are estimates of total intergranular porosity
- the fractured porosity value is the effective fracture porosity reported by Desaulniers (1982)
- Porosity values in the unfractured materials reflect intergranular porosity. Additional fracture porosity is present in the fractured zone. These fractures are accompanied by increased hydraulic conductivities with the result that ground water can potentially move more rapidly along fractures.

The lower till was encountered in the five GLAL boreholes. It is sandy to silty in texture, contains frequent pebbles and ranges in thickness from 0.5 to 5.2 m. The till is also reported in Ministry of the Environment water well records where it is described as 'stony clay', 'clay and gravel' and 'hardpan'. Water well #2776 (Table 4) in the south central portion of the site reports water from 'layered hardpan', however the yield of 1.1 litres per second and a drawdown of about 3 m suggests that the source is more likely a granular deposit or the upper fractured surface of the bedrock. The lower till is not known to be a source of water supply and is included as part of the confining layer except at Borehole GL1 where it is overlain by a fine sand deposit. At other borehole locations the confining layer includes the lower till. Based on textural considerations, the average hydraulic conductivity of the lower till is estimated to be about two orders of magnitude greater than that of the overlying glaciolacustrine and Halton Till deposits. This value ($1x10^{-8}$ m/s) falls within the range for glacial till given by Freeze and Cherry (1979). The porosity is considered to be approximately 0.3 and is reduced slightly (from the value applied to the clayey glaciolacustrine and Halton Till deposits) to reflect the silty sandy textures of the lower till.

Silty clays and clayey silts of the lower glaciolacustrine unit, the Halton Till, and the unfractured portion of the upper glaciolacustrine unit comprise the hydrostratigraphic subunit with the lowest hydraulic conductivity in the study area. This subunit is present in all GLAL boreholes and ranges from approximately 15 to 20 m in thickness (Table 2). Hydraulic conductivities are considered to be similar to values reported by Desaulniers et al. (1981) in similar fine-textured

deposits near Wainfleet. These values range from 1.1×10^{-10} to 8.2×10^{-10} m/s for laboratory tests and from 1.3×10^{-10} to 7.9×10^{-10} m/s for in situ tests. The overall geometric mean is approximately 3×10^{-10} m/s. Porosities ranged from 0.34 to 0.60 at Wainfleet and the approximate average of this range (0.5) is applied to this unit at Site LF-3C. Laboratory and field testing of similar fine-textured glaciolacustrine deposits near Lewiston, New York yielded a range of hydraulic conductivities from 1.4×10^{-10} to 8.7×10^{-10} m/s over depths from 4.7 to 10.0 m (Wehran Engineering, P.C. 1983).

The upper 1 to 2 m of the confining layer (approximately) is most severely fractured, however fracture frequency declines rapidly with depth and the fractures become more tightly closed and fewer. Based on the borehole logs, it is estimated that fracturing is generally limited to depths above 5 m and while occasional fractures are noted at greater depths, they are rare. The deepest fracture noted on the site is at 12.0 m in Borehole GL5. Freeze and Cherry (1979) note that deposits of clayey or silty till and glaciolacustrine deposits in southern Ontario contain networks of hairline fractures which are essentially vertical and which are responsible for hydraulic conductivities one to three orders of magnitude greater than in unfractured materials. Based on this observation the fractured zone is assigned a hydraulic conductivity of 1×10^{-8} m/s which is approximately two orders of magnitude greater than the underlying unfractured deposits.

The fractured zone is included within the confining layer because it is part of the upper glaciolacustrine unit and is clayey and silty in texture. While the higher hydraulic conductivity is conservatively applied over an interval of 5 m,

this fracturing is probably significant only in the upper 1 to 2 m as deeper fractures are more tightly closed and fewer in number. Desaulniers (1982) reports an effective fracture porosity of 0.0001 in glaciolacustrine deposits in Lambton County. These deposits are considered similar to materials at this site and this porosity value is considered to be applicable here.

Several shallow dug wells and cisterns are reported in Table 6 and probably terminate within the fractured zone. The source of water to these wells is in part fractures and in part silty and sandy laminations. Borehole logs indicate occasional silt and fine sand laminae and it is expected that dug or bored wells at most locations would eventually fill with water. Yields from shallow dug or bored wells are expected to be low in the absence of granular materials and peak use would generally be accommodated by well bore storage.

4.2.1.3 Discussion

The confining layer at Site LF-3C is approximately 25 m thick. The GLAL drilling program encountered granular materials in only one borehole and these occur at a depth which does not significantly reduce the overall thickness of the confining layer. The site is characterized by uniform geologic and hydrogeologic conditions and there is a strong likelihood of encountering similar conditions at other locations on the site.

4.2.2 GROUND WATER FLOW REGIME

Infiltration is the source of ground water and differences in hydraulic head provide the driving force for ground water flow systems. At the site, a shallow lateral flow system is considered to exist in the saturated portion of the fractured

zone. A vertical flow system slowly transports small amounts of ground water down and through the confining layer and another mainly lateral flow system occurs within the upper bedrock and associated granular deposits. The site is located in an area where hydraulic gradients in the confining layer are downward. This condition is indicated by a water table which is close to the surface and by water levels in the underlying aquifer which are several metres below ground. Flow systems are discussed below and estimates of flow rates are provided for comparative purposes.

The water table occurs in the fractured zone and its shape is a reflection of topography. Fracturing and ground water flow diminish rapidly to the base of the fractured zone which extends to a depth of about 5 m on the site. The shallow flow system is most active in the upper 1 to 2 m where fracturing is most common and where fracture permeability is best developed. Movement in the shallow flow system is essentially lateral and rates and directions of flow are dependent on elevation differences in the water table. Desaulniers et al. (1981) reports that shallow ground water below depths of 3 to 4 m in fine-textured materials near Wainfleet were recharged prior to the early 1950s based on tritium analyses. The average lateral flow rate in the fractured zone is about 10 m per year based on a gradient of 0.003, an average hydraulic conductivity of 1×10^{-8} m/s, and an average effective fracture porosity of 0.0001. Sample calculations of flow rate employing Darcy's Law are shown in Section 8.6. Estimated fracture flow rates are usually large relative to flow rates in granular porous material because of large differences in porosity. Fracture flows may be unrealistically large if the rates are interpreted as 'straight-

line' pathways because fractures may be complex and interconnections may be indirect or poorly developed. The quantity of flow in the shallow system is greatest when the water table is closest to ground level and the saturated zone is thickest. Flow rates are much less in the unfractured portion of the confining layer.

Ground water potentials in the unfractured portion of the confining layer are downward, however flow rates and amounts of flow are very small. The average downward gradient in wells in the site vicinity (based on static levels reported in water wells at the time of their construction) is about 0.2. In calculating gradients, the water table was selected at ground level to provide a maximum head differential or driving force across the confining layer. Hydraulic gradients measured by Desaulniers et al. (1981) near Wainfleet were vertically downward and ranged between 0.02 and 0.17 over depths to approximately 30 m in fine-textured deposits. Confining layer thicknesses range from 23.1 m in the southeast (Borehole GL3) to 31.4 m in the central part of the site (Borehole GL5). Estimated downward flow rates in the confining layer are summarized in Table 3. Calculations are based on Darcy principles which are presented in Freeze and Cherry (1979) and summarized in Section 8.6. Inspection of Table 3 indicates that estimated vertical ground water velocities in the fractured zone are between three and four orders of magnitude greater than in deeper portions of the confining layer and that the intermediate portion of the confining layer (the unfractured glaciolacustrine units and the Halton Till) is the dominant unit with respect to ground water flow.

A more accurate assessment of ground water flow rates in

the confining layer using advection and diffusion calculations is contained in Appendix D of the report entitled "Site Selection Process, PHase 4A; Selection of Preferred Site(s); Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

TABLE 3: ESTIMATED VERTICAL FLOW RATES IN THE CONFINING LAYER

BOREHOLE	CONFINING LAYER (m/s)		
	FRACTURED ZONE FLOW RATE m/s	UNFRACTURED GLACIO-LACUSTRINE DEPOSITS AND HALTON TILL FLOW RATE m/s	LOWER TILL FLOW RATE m/s
GL1	7×10^{-7}	2×10^{-10}	N/A
GL2	9×10^{-7}	2×10^{-10}	3×10^{-10}
GL3	8×10^{-7}	2×10^{-10}	3×10^{-10}
GL4	8×10^{-7}	2×10^{-10}	3×10^{-10}
GL5	9×10^{-7}	2×20^{-10}	3×10^{-10}

Note: - Hydraulic conductivity and porosity estimates are provided along with the thicknesses of the confining layer sub-units in Table 2.

- Multiply by 3.15×10^{7} for flow in metres per year.

- N/A - Not Applicable

Desaulniers et al. (1981) concluded that pore waters at depth in fine-textured deposits at Wainfleet (and other south-western Ontario locations) originated approximately 8700 to 9800 years ago.

Ground water movement in the bedrock beneath the study area is generally southward. Static water level elevations in wells show an irregular decrease from north to south across the study area of about 4 to 5 m which is equivalent to a gradient of about 0.001. Based on this gradient, an average hydraulic conductivity of 1×10^{-5} m/s (for the upper 5 m of the bedrock) and a porosity of 0.01, the ground water velocity is estimated to be about 1×10^{-6} m/s using Darcy's Law. As indicated previously, fracture flow rates may be unrealistically large if they are interpreted over 'straight-line' distances since fracture connections are usually complex and interconnections may be indirect or poorly developed.

4.2.3 GROUND WATER USE

Water use information is based on water well record data and on data collected from residents and landowners on the site and on adjacent properties.

4.2.3.1 Availability

Water supplies for domestic, stock, and general agricultural purposes are obtained from drilled wells, dug wells, cisterns, and dugouts. Occasionally, drinking water is brought in from offsite locations. Water use information is summarized according to type of source in Figure 8 (in map pocket) and is supported by interview data summaries in Table 6 (Section 8.3).

Based on water well records and field information surveys, the bedrock and basal granular deposits are sources of water supply to drilled wells in the study area. There appear to be no Ministry of the Environment well records for any dug or bored wells in the study area. In most cases ,adequate water supplies are obtained from the bedrock within the upper 3 m,

although penetration depths of up to 14 m are reported. Test pumping rates are generally less than 1.5 litres per second (L/s) with drawdowns of less than 3 m in about half the cases. Lower test pumping rates and higher drawdowns appear to characterize the southwest corner of the study area where one well was reportedly abandoned due to insufficient supply after penetrating approximately 2 m of 'grey shale'. The locations of wells which obtain water from sand and gravel deposits overlying the bedrock follow no apparent pattern. In some cases drillers have reported granular deposits but have cased through them to obtain a bedrock water supply.

Several additional dug/bored and drilled wells were reported during field information surveys. These wells range in depth from 2 to 18 m and are used for domestic, stock, and general agricultural purposes. Five dug or bored wells are known on the site. Three (one is abandoned) are north of Beaver Creek and two (one is abandoned) are in the southeast near the Welland River flood plain. These wells are about a metre in diameter, generally less than 10 m deep and reportedly provide reliable supplies. No yields are available for the dug wells, however it is considered that they are generally low and that peak use is accommodated by storage.

Rainwater cisterns are a common source of additional water supply in the area and some properties have more than one. Most cisterns 'dry up' during periods of low rainfall and a few are maintained with trucked water. Dugouts and off-stream ponds are used for stock and agricultural purposes. It is considered that many dugouts penetrate the water table although some may rely on surface runoff.

Most residents on the site and in the area rely on water supplies from more than one source. Combinations of drilled wells, dug wells, cisterns, dugouts, and ponds are in common use to resolve water quantity and quality problems.

4.2.3.2 Quality

Ground water quality from the bedrock and from granular deposits near the bedrock contact (as reported in the water well records) ranges from 'fresh' to 'salty', 'sulphurous' and 'mineralized'. Two wells (#1574 and #2235; Table 4, Section 8.4) are reportedly abandoned for reasons of poor quality, however, both of these are more than a kilometre offsite. Although slightly more than half the water well records indicate 'fresh' water from the bedrock and from granular deposits which occur at or near near the bedrock contact, most of the interview information indicates that the bedrock and granular deposits yield 'sulphurous',' salty' and 'mineralized' water. Since yields do not seem to be a general problem, it is considered that the use of dug wells, cisterns, and ponds is a response to water quality problems in the deeper aquifers.

Water analyses from two drilled wells in the Wellandport area indicate chloride and hardness levels of 1800 and 2200 mg/L respectively. These analyses were conducted in 1967 by the Ministry of the Environment (then the Ontario Water Resources Commission) and while the well locations are not provided, they are considered to be generally representative of water quality in the Salina bedrock in the area. Water quality in dug wells identified during the "Walk and Talk" information survey is reported as 'hard', 'soft' and 'good for drinking', however no chemical analyses are available from these wells.

4.2.4 POTENTIAL CONTAMINANT PATHWAYS

In general, there are two hydrogeologic pathways by which contaminants could potentially leave this site; these are (1) natural pathways along ground water flow systems and (2) man-made pathways which follow such structures as abandoned and unplugged wells and tile drains. The natural pathways retard contaminant movement because of the low hydraulic conductivity of the confining layer. Natural pathways are discussed in Site Hydrogeology (4.2.1) and Ground Water Flow Regime (4.2.2).

Efforts have been made to identify and locate man-made structures such as water wells, gas wells, tile drainage systems and excavations which may be located on the site. These structures could act as pathways along which contaminants could potentially move. For example, improperly sealed and abandoned wells which penetrate the confining layer could provide access to the underlying aquifer. Shallow structures such as granular trench backfill and drainage tiles could provide direct access to surface water and shallow ground water. There are twelve water wells (seven drilled and five dug or bored) on the site. All were identified through field interviews and discussions and additional information was obtained for two of the drilled wells from Ministry of the Environment files. Two of the dug or bored wells are abandoned, three drilled wells are unused, and one drilled well is abandoned. The drilled well belonged to a homestead and could not be located in the field. Well locations are shown in Figures 4 and 8. It is considered that drilled wells probably penetrate the confining layer. Gas wells are common west of the site, however none are known on the site. Approximately 57 ha of the 259 ha site is reported to be tile drained. The tile systems drain via local ditches and water courses which

discharge to the Welland River. The drains are usually buried within 2 m of the surface at spacings which depend on local conditions. Tile drain information is contained on field interview information sheets compiled by Ecologistics Limited. Excavations are believed to be limited to the immediate vicinity of buildings on the site and no extensive corridors of permeable back fill materials were identified from the interview sheets.

5.0 GEOTECHNICAL CONSIDERATIONS

This section provides a preliminary assessment of Site LF-3C from a soils engineering point of view. The geologic setting is described in detail in Section 4.0 of this report.

The geologic data base has been supplemented by standard penetration split spoon tests at 1.5 m intervals in each of the five GLAL boreholes. The standard penetration (N) values have been used as a guide in estimating the relative density and consistency of the various soils. Shear strengths noted here are estimated from blow-count shear-strength relationships obtained from other studies in similar materials in the Niagara Peninsula. Moisture contents are presented along with N values on the geologic logs in Section 8.5. The geotechnical conditions at this site as related to the geologic setting are described below.

There is a desiccated crust of about 6 to 7 m in thickness over the site. This crust has a generally very stiff consistency, based on N values that range between 15 and 30

(blows per 0.3 m). As such, the undrained shear strength varies from about 100 to more than 200 kPa. The moisture contents of these desiccated silty clays were in the 20 to 30% range which are drier than the plastic limit to about the plastic limit.

Upper glaciolacustrine deposits below the desiccated crust is normally consolidated or, in a state of stress due only to the weight of soils above it. In general, this zone has a stiff consistency with N values in the 8 to 10 range. This corresponds to undrained shear strengths of approximately 50 kPa with local areas approaching 100 kPa. These are cohesive soils with moisture contents of 30 to 40% indicating that they are generally wetter than their plastic limit.

The Halton Till is also cohesive and of a silty clay texture but is over-consolidated because deposition occurred beneath glacial ice. This unit lies below construction depths and no problems are foreseen related to loading from above. Undrained shear strengths for the Halton Till are in the 50 to 200 kPa range.

The lower glaciolacustrine deposits below the Halton Till appear over-consolidated probably as a result of the deposition of the till above them. Undrained shear strengths are generally between 50 to 100 kPa. They are considered not to present a problem based on these preliminary findings.

The lower till which overlies the bedrock is typically dense to very dense with N values generally greater than 50. The in situ moisture contents were generally less than 10%.

The preliminary assessment based on data from the GLAL boreholes indicates that no significant soils engineering problems will be encountered provided that the guidelines suggested below are followed. It is considered that sub-surface aspects can be handled with proper design and standard techniques. As a general guide, temporary excavations up to 10 to 15 m below ground can be undertaken at 2:1 side slopes. Excavations that extend deeper into the softer, clayey, upper glaciolacustrine deposits will have to be investigated in greater detail from a stress relief and stability perspective.

Treated waste residues could be placed to thicknesses of about 1.5 times the depths of the cells, based on a density of 1.35 tonnes per cubic metre without creating a surcharge load. Provided there is no surcharge load within the cell base, settlement will be minimal. As well, no problems related to bearing pressure are anticipated. Greater thicknesses of fill may be possible without creating a shear failure or un-acceptable settlement but will require detailed investigation.

For the above ground option only, fills could be con-structed to heights of about 12 to 15 m above ground level before bearing pressure failures become a problem. For fills of this height, some settlement of the sub-soils would be likely and would require detailed investigation. There is insufficient geotechnical data available at this stage of the study to estimate the magnitude of any settlement.

The desiccated crust which underlies the site is gener-ally very stiff in consistency. The allowable bearing pressure for this crust is generally suitable for light to medium weight structures with shallow strip or conventional pad footings. As

a guide, allowable bearing pressure of 150 kPa can be adopted for footings founded in the upper 2 m of the desiccated crust. Settlement of these structures should be within tolerable limits provided that most of the applied foundation stresses are dissipated within the crust.

For heavy structures it will likely be necessary to transfer loads to the lower till where allowable bearing pressures are available. This aspect will require a detailed foundation investigation during Phase 4B work on the preferred site.

The clayey subsoils on the site are workable; however, due to their 'wet' and 'sticky' nature they will be a nuisance from a materials handling and trafficability perspective. This nuisance aspect will be aggravated during wet weather conditions.

6.0 SUMMARY

Site LF-3C is located on the Haldimand Clay Plain in West Lincoln Township. It is situated at the contact of the Salina and Guelph formations and is underlain by shales and dolostones. Overburden thicknesses vary from 25 to 30 m and consist of a lower silty sandy till and clayey glaciolacustrine deposits separated by clayey Halton Till. There is also evidence of a discontinuous basal granular deposit. The two major hydrostratigraphic units are (1) a bedrock and granular aquifer and (2) a confining layer which extends from surface to the first significant granular layer or to bedrock. The

confining layer usually includes three hydrostratigraphic subunits which are (1) the lower till, (2) the lower glaciolacustrine unit, the Halton Till, and the unfractured glaciolacustrine unit, and (3) the surficial fractured zone.

The shallow flow system in the fractured zone is characterized by mainly lateral flow at rates of approximately 10 m per year. Primarily vertical flow in the unfractured portions of the confining layer occurs at an average rate of 0.005 m per year and mainly vertical flow in the lower till occurs at an average rate of about 0.01 m per year. Man-made pathways to the underlying aquifer or to offsite locations include wells, linear excavations, and tile drainage systems.

Soils engineering aspects at this site can be handled with proper design and standard techniques. Temporary excavations can safely extend to 10 to 15 m below ground surface at 2:1 side slopes. Treated waste residues can be placed to thicknesses of about 1.5 times the depths of the cells. For the above ground option, fill heights of 12 to 15 m above ground surface at 3:1 side slopes will be stable. The desiccated crust beneath the site will support light to medium weight structures. However, for heavy structures it will likely be necessary to transfer loads to the lower till. Although the clayey subsoils are workable, their 'wet' and 'sticky' nature will create a nuisance from a materials handling and trafficability perspective.

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8.0 SUPPORTING INFORMATION

8.1 SUMMARY OF WATER WELL DATA (TABLE 4)

8.2 SUMMARY OF OIL AND GAS WELL DATA (TABLE 5)

8.3 SUMMARY OF SITE INTERVIEW (WALK AND TALK) DATA (TABLE 6)

8.4 FIELD STATION DESCRIPTIONS

8.5 BOREHOLE LOGS

8.6 SUPPORTING CALCULATIONS AND METHODS

8.7 GLOSSARY OF SELECTED TERMS

8.8 DETAILED FIELD METHODS

8.1 SUMMARY OF WATER WELL DATA

Water well locations are shown in Figure 4 (in map pocket).

Copies of original Water Well Records obtained from the Ministry of the Environment (MOE) were used for the following data summary and are on file.

Measurements, dimensions, and quantities on the Water Well Records are in Imperial units but are presented in metric units in the summary.

Water well locations were plotted on 1:10 000 scale maps for this project and elevations were re-estimated based on the more accurate contours on these maps. Well elevations are above sea level (ASL) and are estimated to the nearest metre.

Well records are arranged in numerical order.

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF- 3C

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
211	MILLER, K CON. 1, LOT 21, TOWN OF DUNVILLE (PREV. MOULTON TWP.)	180	APR 1958	14.3	28.7	SALTY	29.9	4.6	6.1	2.5	STOCK	0.0	19.8	CLAY
												19.8	29.0	HARDPAN
												29.0	29.9	GRAVEL
222	MILLER, T CON. 1, LOT 21 TOWN OF DUNVILLE (PREV. MOULTON TWP.)	180	FEB 1947	15.9	33.5	"BLACK"	21.6	4.3	--	--	STOCK	0.0	21.6	CLAY, BOULDERS, GRAVEL
												21.6	33.5	ROCK
412	VAUGHAN, L BF, LOT 7 WEST LINCOLN TWP. (PREV.GAINSBOROUGH TWP)	--	NOV 1947	15.9	--	SULPHUROUS	22.9	4.3	--	7.7		0.0	19.8	CLAY
												19.8	22.9	GRAVEL
												22.9	38.5	ROCK
413	VAUGHAN, D BF, LOT 7 WEST LINCOLN TWP. (PREV.GAINSBOROUGH TWP)	--	NOV 1947	15.9	--	SULPHUROUS SALTY	27.4	4.9	--	7.7		0.0	22.3	CLAY
												22.3	22.6	GRAVEL
												22.6	23.0	ROCK LEDGE
												23.0	26.5	HARDPAN AND STONES
												26.5	27.4	GRAVEL
												27.4	32.0	ROCK
416	GRAHAM, H CON. 1, LOT 2 WEST LINCOLN TWP. (PREV.GAINSBOROUGH TWP)	180	MAY 1947	14.3	7.6	HARD MINERALIZED	21.3	--	--	0.6	STOCK	0.0	20.1	CLAY
												20.1	21.3	FINE SAND
												21.3	28.0	GREY SHALE, LIMESTONE
417	ROGOWSKI, K CON 1, LOT 6 WEST LINCOLN TWP. (PREV.GAINSBOROUGH TWP)	180	DEC 1958	15.9	33.5 35.1	SULPHUROUS	31.1	5.5	9.0	0.3	STOCK	0.0	12.2	YELLOW CLAY
												12.2	24.4	RED CLAY
												24.4	31.1	SAND, HARDPAN, BOULDERS
												31.1	35.1	GREY SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF- 3C

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
418	DOUMA, H CON.1, LOT 8 WEST LINCOLN TWP. (PREV.GAINSBOROUGH TWP)	180	AUG 1958	15.9	30.5	FRESH	29.3	4.3	4.6	1.3	STOCK	0 22.9 28.7	22.9 28.7 30.5	CLAY GRAVEL, CLAY ROCK
426	HANNA, J.A. CON 2, LOT 2 WEST LINCOLN TWP. (PREV.GAINSBOROUGH TWP)	181	FEB 1949	14.3	--	FRESH	25.3	5.5	--	--	STOCK	0.0 21.3 24.4	21.3 24.4 25.3	CLAY HARDPAN GRAVEL
427	COSLY, E CON 2, LOT 3 WEST LINCOLN TWP. (PREV.GAINSBOROUGH TWP)	181	MAY 1948	14.3	21.9	SULPHUROUS HARD	21.9	6.1	--	--	STOCK	0.0 21.9 22.3	21.9 22.3	CLAY, TOPSOIL GRAVEL ROCK
437	KUTZA, N CON 3, LOT 7 WEST LINCOLN TWP (PREV.GAINSBOROUGH TWP)	180	AUG 1952	15.9	32.3	SULPHUROUS MINERALIZED HARD	30.5	3.7	--	1.5	STOCK	0.0 30.5	30.5	BLUE CLAY LIMESTONE
440	REECE, A CON 3, LOT 9 WEST LINCOLN TWP. (PREV.GAINSBOROUGH TWP)	180	MAY 1962	15.9	32.9	FRESH	32.9	4.9	0.8	--	STOCK	0.0 21.3	21.3 32.9	BLUE CLAY GRAVEL, BOULDERS
1359	REDEKOP, H.H. CON 1, LOT 20 TOWN OF DUNNVILLE (PREV. MOULTON TWP.)	177	JUN 1969	15.9	23.5 25.6	FRESH @ 23.47 SULPHUROUS @ 25.60	23.5	3.7	21.3	1	DOMESTIC	0.0 3.7 20.4 22.9 23.5 25.6	3.7 20.4 22.9 23.5 25.6 29.0	BROWN CLAY BLUE CLAY BLUE CLAY, GRAVEL GREY GRAVEL GREY LIMESTONE BLUE ROCK

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF- 3C

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
1451	OUTRAM, H CON 1, LOT 21 TOWN OF DUNNVILLE (PREV. MOULTON TWP.)	177	MAY 1971	23.16	FRESH	22.91	23.2	4.6	1.9	--	DOMESTIC	0.0	4.6	BROWN CLAY
												4.6	18.9	RED CLAY
												18.9	22.9	BLUE CLAY, GRAVEL
												22.9	23.2	GREY GRAVEL, SHALE
1515	MCCULLUM, G. CON 1, LOT 20 TOWN OF DUNNVILLE (PREV. MOULTON TWP.)	177	OCT 1971	15.9	24.1	FRESH	24.1	4.3	3.7	1.0	DOMESTIC	0.0	3.7	BROWN CLAY, PACKED
												3.7	18.3	BLUE CLAY, SOFT
												18.3	24.1	GREY SHALE, CLAY, LAYERED
												24.1	25.9	BLUE SHALE, LOOSE
1516	BACHELLIER, R CON 1, LOT 20 TOWN OF DUNNVILLE (PREV. MOULTON TWP.)	178	NOV 1971	15.9	22.9	FRESH	19.8	4.3	18.3	1	DOMESTIC	0.0	1.5	BROWN TOPSOIL
												1.5	9.1	BROWN CLAY
												9.1	18.3	RED CLAY
												18.3	24.4	RED SHALE
1526	SMITH, R CON 1, LOT 20 TOWN OF DUNNVILLE (PREV. MOULTON TWP.)	177	MAR 1972	15.9	23.2	FRESH	23.2	4.3	16.8	0.8	DOMESTIC	0.0	8.5	BROWN CLAY
												8.5	18.0	GREY CLAY
												18.0	22.9	RED CLAY, GRAVEL
												22.9	23.2	GREY SHALE
1547	ALLEN, D CON 1, LOT 20 TOWN OF DUNNVILLE (PREV. MOULTON TWP.)	178	MAY 1972	15.9	24.4	FRESH	23.2	4.6	7.6	0.8	DOMESTIC	0.0	8.8	BROWN CLAY
												8.8	18.3	GREY CLAY
												18.3	23.2	RED CLAY, GRAVEL
												23.2	24.7	GREY LIMESTONE
1572	WELLANDPORT CONST. CON 1, LOT 20 TOWN OF DUNNVILLE (PREV. MOULTON TWP.)	177	SEP 1972	15.9	23.5	FRESH	22.9	4.3	35.1	0.1	DOMESTIC	0.0	7.0	BROWN CLAY
												7.0	20.4	GREY CLAY
												20.4	22.9	GREY CLAY, GRAVEL
												22.9	36.6	GREY LIMESTONE
1573	WELLANDPORT CONST, CON 1, LOT 20 TOWN OF DUNNVILLE (PREV. MOULTON TWP.)	177	SEP 1972	15.9	24.4	FRESH	23.2	4.6	27.4	0.1	--	0.0	7.3	BROWN CLAY
												7.3	20.7	GREY CLAY
												20.7	23.2	GREY CLAY, GRAVEL
												23.2	28.0	GREY LIMESTONE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF- 3C

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
1574	KRUEGEL, H CON 1, LOT 20 TOWN OF DUNNVILLE (PREV. MOULTON TWP.)	177	SEP 1972	15.9	23.5	SALTY	21.6	3.7	6.7	1.1	DOMESTIC	0.0	6.7	BROWN CLAY
												6.7	18.3	GREY CLAY
												18.3	21.3	GREY CLAY, GRAVEL
												21.3	23.8	GREY LIMESTONE
1604	SCHOUSTEN, J CON 1, LOT 21 TOWN OF DUNNVILLE (PREV. MOULTON TWP.)	177	FEB 1973	15.9	19.8	FRESH	18.6	2.4	12.2	1.5	DOMESTIC	0.0	1.2	TOPSOIL
												1.2	7.9	BROWN CLAY
												7.9	18.3	BLUE CLAY
												18.3	20.1	GREY SHALE
1605	SCHOUSTEN, J IBBOTT, R CON 1, LOT 21 TOWN OF DUNNVILLE (PREV. MOULTON TWP.)	177	JAN 1973	15.9	18.3	FRESH	18.3	1.2	18.3	0.1	DOMESTIC	0.0	1.2	TOPSOIL
												1.2	8.5	BROWN CLAY
												8.5	18.0	BLUE CLAY
												18.0	18.3	GREY SHALE
2234	ROBINS, A CON 7, LOT 52 WAINFLEET TWP.	177	APR 1948	16.8	--	FRESH	24.7	4	--	--	STOCK DOMESTIC	0.0	18.3	CLAY
												18.3	21.3	HARDPAN
												21.3	24.4	GRAVEL
												24.4	25.3	ROCK
2235	ROBINS, O CON 7, LOT 56 WAINFLEET TWP.	176	APR 1958	--	25	SALTY	--	2.4	4.9	2.4	ABANDONED	0.0	23.8	CLAY
												23.8	24.1	MEDIUM SAND, SILT
												24.1	25.9	GREY SHALE
2243	DOUMA, H CON 2, LOT 10 WEST LINCOLN TWP. (PREV.GAINSBOROUGH TWP)	180	MAY 1972	15.9	27.1	FRESH	26.5	7.6	12.2	0.9	DOMESTIC STOCK	0.0	24.4	GREY CLAY
												24.4	26.5	CLAY, GRAVEL
												26.5	27.1	ROCK
2279	BUITENWERF SEEDS CON 3, LOT 4 WEST LINCOLN TWP. (PREV.GAINSBOROUGH TWP)	182	JUN 1973	15.9	20.1	FRESH	19.8	5.5	8.2	2.3	STOCK DOMESTIC	0.0	17.1	BROWN CLAY
												17.1	19.8	RED CLAY, STONES
												19.8	20.4	GREY LIMESTONE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF- 3C

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2489	WOHLFAHST, H CON 3, LOT 4 WEST LINCOLN TWP. (PREV.GAINSBOROUGH TWP)	182	JUL 1975	15.9	21.3	FRESH	20.6	6.7	7.6	1.5	DOMESTIC IRRIG-ATION	0.0 19.8 20.4	19.8 20.4 21.3	GREY CLAY CLAY, GRAVEL ROCK
2524	SMIT, R CON 2, LOT 2 WEST LINCOLN TWP. (PREV.GAINSBOROUGH TWP)	180	JAN 1976	15.9	27.4	SULPHUROUS	26.5	1.8	1.8	1.5	STOCK	0 8.5 18.3 26.2	8.5 18.3 26.2 27.7	BROWN CLAY GREY CLAY RED CLAY, GRAVEL GREY LIMESTONE
2570	CASSIDAY, J CON 7, LOT 59 WEST LINCOLN TWP. (PREV.GAINSBOROUGH TWP)	181	SEP 1970	15.9	29.9	FRESH	28.7	12.2	12.2	2.3	DOMESTIC	0.0 1.8 3.0 9.1 27.4 28.7	1.8 3.0 9.1 27.4 28.7 30.5	TOPSOIL CLAY TOPSOIL BROWN CLAY BLUE CLAY GREY SHALE LIMESTONE
2776	DOUMA, B CON 1, LOT 6 WEST LINCOLN TWP. (PREV.GAINSBOROUGH TWP)	179	SEP 1979	15.9	23.8	SULPHUROUS	24	6.1	9.1	1.1	DOMESTIC	0.0 4.6 18.3 23.8	4.6 18.3 23.8 24.1	GREY CLAY, PACKED GREY CLAY, DENSE BROWN CLAY, DENSE GREY HARDPAN, LAYERED

8.2 SUMMARY OF OIL AND GAS WELL DATA

Oil and gas well locations are shown in Figure 4 (in map pocket).

Copies of original oil and gas well records were obtained from the Ministry of Natural Resources (MNR) office in London, Ontario. Locations of abandoned oil and gas wells were obtained from the MNR and from local residents and are numbered 1 to 49 in Figure 4. There is no information available (aside from location) for these wells.

Imperial units are used in the original well logs and these have been changed to metric units in the summary. Where ground elevations were supplied, they have been verified using contours on 1:10 000 scale maps. Where no elevations were supplied, elevations are estimated from the base maps. All elevations are above sea level (ASL) and are shown to the nearest metre.

Copies of oil and gas well records and mapping are on file.

TABLE 5. SUMMARY OF OIL & GAS WELL DATA

Site: LF- 3C
Sheet 1 of 1

WELL BOREHOLE No.	LOCATION location	GROUND ELEVATION (m ASL)	FROM FROM	TO TO	MATERIALS DESCRIPTION	COMMENTS
315527	CON. 1, LOT 3 WEST LINCOLN TWP. R.M. OF NIAGARA	180	0 13	13 163	OVERBURDEN BEDROCK	GAS PRODUCER
535467	CON. 3, LOT 5 WEST LINCOLN TWP. R.M. OF NIAGARA	180	0 14.1	14.1 159.5	OVERBURDEN BEDROCK	GAS PRODUCER
825771	CON. 2, LOT 8 WEST LINCOLN TWP. R.M. OF NIAGARA	178	0 27.8	27.8 164	OVERBURDEN BEDROCK	GAS PRODUCER
1025521	CON. 2, LOT 10 WEST LINCOLN TWP. R.M. OF NIAGARA	181	0 23.8	23.8 152	OVERBURDEN BEDROCK	GAS PRODUCER
835763	CON. 3, LOT 8 WEST LINCOLN TWP. R.M. OF NIAGARA	182	0 21.4	21.4 158	OVERBURDEN BEDROCK	GAS PRODUCER
1 to 45 *	VARIOUS		NO DATA AVAILABLE			ABANDONED WELLS FROM MNR MAPS
46 to 49	VARIOUS		NO DATA AVAILABLE			WELL LOCATIONS FROM MR.H.BLACK (RESIDENT)

Gartner Lee Associates Limited

NOTE: Data on wells condensed from records on file with the Ministry of Natural Resources, London, Ontario.

* Well locations obtained from Ministry of Natural Resources, Petroleum Resources Map E-15 (NTS Reference 30L/13, East Dunville), Map F15 (NTS Reference 30M/14, East Grimsby) and Map F-16 (NTS Reference 30M/13, West Niagara).

8.3 SUMMARY OF SITE INTERVIEW (WALK AND TALK) DATA

Water use data from Ecologistics Limited field interview (Walk and Talk) forms is presented in Figure 8 (in map pocket). Water use data were collected from residents on the site and adjacent properties.

Water use data is augmented with information collected by Gartner Lee Associates Limited staff during discussions with local interest groups and individuals.

Deeper drilled wells are considered to terminate in bedrock where supporting evidence is available.

Although most of the information was provided in Imperial units, it has been converted to metric units for uniformity with the remainder of the report.

Interview numbers are related to identifications assigned by Ecologistics Limited during the collection of these data.

Copies of the survey forms are on file.

West Lincoln Township was formerly Gainsborough Township.

A copy of the water resources form is included at the end of this section.

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site LF-3C Sheet 1/7

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s	Cistern	Remarks
1	Ralph & Harry Janssens	5 West Lincoln Twp.	2	219-2			✓	Cistern supplies household Pond on property, are new, haven't gone dry
2	Mrs. Zumstein	6 West Lincoln Twp.	2	104-1			✓	Cistern supplies household - water quality soft, rainwater
3	Mr. & Mrs. G. Gilmer	7,8 West Lincoln Twp.	2	81-2	✓	✓		Drilled well (No MOE record) - 12.2 m (40 ft.) deep - supplies household - water quality hard, sulphurous Dug/Bored well (No MOE record) - 30.5 m (100 ft.) deep - supplies livestock - water quality hard, sulphurous Pond on property
4	Mr. John Aantjes	8 West Lincoln Twp.	1	91-2	✓		✓	Cistern supplies household - rainwater, dries up most summers with little rain Drilled well (No MOE record) - supplies livestock - water quality sulphurous
5	Mr. David Vanderweir	5 West Lincoln Twp.	1	818			✓	Cistern supplies household - rainwater and trucked in water, goes dry 6 times/year. Pond supplies livestock
6	Mr. Philip Davis	6 West Lincoln Twp.	1	69-1			✓	Cistern supplies household - rainwater, soft water quality Drinking water trucked in Pond on property

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site LF-3C Sheet 2/7

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
7	Mr. J. Swayze	7 West Lincoln Twp.	1	61-2	✓	✓✓		Dug/Bored Well (No MOE record) - 2.4 m (8 ft.) deep - supplies household - water quality soft Dug/Bored well (No MOE record) - 3.7 m (12 ft.) deep - supplies livestock - water quality soft Drilled well (MOE well 418) - 30.5 m (100 ft.) deep - supplies livestock - water quality sulphurous Pond on property, dries up in summer
8	Mr. J. Krahne	7 West Lincoln Twp.	1	242-1	✓		✓	Cistern supplies household - rainwater, water quality soft - dries up 2 to 3 times per year Drilled well (No MOE record) - 20.4 m (67 ft.) deep - 10.2 cm (4 in.) pipe installed to 17.7 m (58 ft.) - well incomplete, not used
9	Mr. Robert Douma	6 West Lincoln Twp.	1	63-2	✓		✓	Drilled well (MOE well 2776) - 31.7 m (104 ft.) deep - supplies livestock - water quality, sulphurous, black dirty Cistern supplies household - rainwater, water quality soft - goes dry 1 year in 5 Pond on property

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site LF-3C Sheet 3/7

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
10	Mr. Harry Van Marrum	5 West Lincoln Twp.	1	694			✓	Cistern on property - good water quality Pond on property - good water quality
11	Mr. & Mrs. Ted Wisniewski	5 West Lincoln Twp.	1	65-2			✓✓✓✓	Cisterns (3) supply household - good water quality roof run-off - short of water a couple of times Cistern (1) supplies livestock - good water quality Pond on property
12	Albertus Zantingh	4 West Lincoln Twp.	1	105-2			✓	Cistern supplies household - rainwater, good water quality - never goes dry Pond supplies livestock - water quality not suitable for domestic drinking water
13	Mr. Louis Douma	6 West Lincoln Twp.	1	62-1a	✓		✓	Cistern supplies household - rainwater, water quality soft - occasionally dries up Drilled well (MOE well 417) - 30.5 m (100 ft.) deep - supplies livestock
14	Mr. & Mrs. Elgin Cosby	7 West Lincoln Twp.	1	115-2		✓✓	✓	Dug/Bored well (No MOE record) - 3.6 m (12 ft.) deep - supplies household, not used for drinking - water quality hard sulphurous - never goes dry Dug/Bored well (No MOE record) - not used (cont'd.)

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site LF-3C Sheet 4/7

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored well(s)	Cistern	Remarks
14 (cont'd)	Mr. & Mrs. Elgin Cosby							Cistern supplies household - rainwater, water quality soft - goes dry 3 times per year in dry year Ponds (2) on property - one pond pumped for 48 hrs. couldn't drain
15	Mr. Edward Peaire	7 West Lincoln Twp.	BF	7-2		✓✓	✓	Dug/Bored well (No MOE record) - 9.8 m (32 ft.) deep - supplies household - water quality hard - never goes dry Dug/Bored Well (No MOE record) - 6.1 m (20 ft.) deep - supplies livestock - water quality hard - never goes dry Cistern supplies livestock Pond on property
16	Mr. Norm Vaughan	7 West Lincoln Twp.	BF	90-2			✓	Cistern supplies household - soft water quality - goes dry nine times per year
17	W. Van Soellen	5 West Lincoln Twp.	BF	92-2		✓		Dug/Bored well (No MOE record) - 3.0 m (10 ft.) deep - supplies household and livestock - good water quality - spring fed Pond on property

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site LF-3C Sheet 5/7

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/Bored well(s)	Cistern	Remarks
18	Mr. & Mrs. G. Gerryts	8 West Lincoln Twp.	BF	224-2	✓		✓	Cistern supplies household - water quality soft - dries up twice a year Drilled well (No MOE record - supplied livestock, not in use - water quality, sulphurous, salty, high iron content Stream supplies livestock
19	ELCHO UNITED CHURCH (Mr. Norman Vaughan)	5 West Lincoln Twp.	2	127-1				Bottled water brought from homes
20	Mr. Loyal Krick	6 West Lincoln Twp.	1	281-2 282-2	✓	✓	✓	Dug/Bored well (No MOE record) - supplies household Cistern supplies household - soft water quality - not sealed, spring water seeps in Drilled well (No MOE record) - 31.1 m (102 ft.) deep - water level 1.8 m (6 ft.) from top - supplied livestock, not in use Ponds on property
21	Ralph & Harry Janssens	7 West Lincoln Twp.	1	219-2	✓			Drilled well (No MOE record) - supplied household - water quality sulphurous - not in use (GLAL field info.)
22	W. Gerryts	4 West Lincoln Twp.	BF	102-2			✓	Cistern supplies household - water quality soft - never goes dry Pond supplies livestock - soft water quality

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site LF-3C Sheet 6/7

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
23	Archie Huizinga	5 West Lincoln Twp.	BF	83-2			✓	Cistern supplies household - roof water, soft water quality - dried up a few times Pond supplies livestock - fed by tile drains
24	Mr. Norman Vaughan	7 West Lincoln Twp.	BF	90-2	✓			Drilled well (MOE well 413) - 21.9 m (72 ft.) deep - supplies livestock - water quality, hard, sulphurous, saline
25	Harley Black	6 West Lincoln Twp.	1	GLAL field visit		✓		Dug well (No MOE record) - water level about 1. m (4 ft.) from surface - abandoned well, located by backhoe excavation, stone lined well
26	Harley Black & Loyal Krick	6 West Lincoln Twp.	1	GLAL field visit	✓			Drilled well (No MOE record) - supplied livestock, used to fill pond - water quality salty, black colour - well not used (see No. 20)
27	Mr. J. Krahne	7 West Lincoln Twp.	1	GLAL field visit	✓			Drilled well (No MOE record) - 20.4 m (67 ft.) deep - casing inserted to 17.7 m (58') - well incomplete, not used (see No. 8)

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site LE-3C Sheet 7/7

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
28	Mrs. N. Vaughan & Mr. H. Black	6 West Lincoln Twp.	1	GLAL field visit	✓			Drilled well (No MOE record) - located on E. Vaughan homestead - water quality reported to be good - abandoned
29	Mr. Elgin Cosby	7 West Lincoln Twp.	1	GLAL field visit		✓		Dug/Bored well (No MOE record) - located at collapsed barn under rubble - flowing conditions at well - abandoned
30	Mr. Wright	4 West Lincoln Twp.	2	857			✓✓	Cistern supplies household - rainwater Cistern supplies livestock - rainwater
31-35	Mr. H. Black			OWMC field visit	(5)			Well locations provided by Mr. H. Black. (No MOE records) - well type unknown - no other information
36	Mr. H. Black			GLAL and OWMC field visit	✓			Drilled well (No MOE record) - water quality sulphury, salty - not used

Interview Identification Number: _____

PHYSICAL RESOURCES - WATER

We are interested in the water used on this property: where it comes from, its quality, and how much you use.

1. What is this household's source of supply for domestic water? (e.g., drinking, laundry, toilet)

drilled water	☐	Locate on map with symbol Dr-H
dug wells	☐	Locate on map with symbol Du-H
stream water	☐	Locate on map with symbol *SW-H
cistern	☐	Locate on map with symbol *C-H
bottled water	☐	
municipal main	☐	
other, specify		_____

2. What is the water supply for the livestock and irrigation on this property?

drilled wells	☐	Locate on map with symbol Dr-A
dug wells	☐	Locate on map with symbol Du-A
streams or dams	☐	Locate on map with symbol *SW-A
cisterns	☐	
municipal main	☐	
other (e.g., ponds)		_____

3. Are there any streams or ponds on your property?

streams	Yes ☐	No ☐
ponds	Yes ☐	No ☐

4. What can you tell us about the quality of the water

a) you use or drink? (hard, soft, sulphurous, iron, salty, etc.) _____

_____

_____

b) in the streams or ponds? _____

_____

_____

5. Do the wells, cisterns or streams that you use for water supply ever go dry? If so, how often? _____

_____

_____

_____

Interview Identification Number: _____

6. Can you tell us anything about the construction of the wells? (e.g., when they were drilled, depth, type of pump, name of the driller) _____

7. Has any portion of your property been filled or excavated? If so, please show where on the map. (Locate on map with symbol EV.)

8. Do you know where there are any gas or oil wells on your property or the property you farm - in use or abandoned? Please show their locations on the map with the symbol GW.

9. Please tell us about any problems with flooding in the creeks and streams on your property. Please show locations of the flooded areas on the map. (Locate with symbol FA.)

8.4 FIELD STATION DESCRIPTIONS

Field stations including hand auger holes, hand dug test pits and backhoe test pits are located in Figure 4 (in map pocket).

A standard 25 mm soils auger was used to examine soil profiles, and a tile spade was used to dig shallow pits. A backhoe was used by a resident of the area on behalf of the Chippawa Watershed Group. Test pits were filled in or partially flooded at the time of field visits.

8.4 FIELD STATION DESCRIPTIONS, SITE LF-3C

Field Station #1
Hand auger hole
0-0.6 m medium brown silt
0.6-0.9 m grey brown to brown grey silty clay
0.9-1.1 m mottled grey silty clay

Field Station #2
Hand auger hole
0-0.6 m brown silty clay

Field Station #3
Back hoe test pit
The excavation was the site of an old, stone lined dug well. The hole was originally dug to a depth of about 2.4 m but had sloughed in at the time of the field check. Water was observed at about 0.6-0.9 m from ground surface. The sidewalls of the excavation down to 0.6 m showed the following:
0-0.6 m grey to grey brown silty clay with rusty, reddish brown staining

Field Station #4
Hand auger hole
0-1.7 medium to light grey clay, stony, reddish brown staining, some organic material
1.7-1.8 m grey and brown clay, shows reddish brown staining, contains some organic material
Water level in open hole estimated at 0.6 m below ground.

Field Station #5
Hand auger hole located close to road (in bush)
0-0.8 m brown clayey silt, slightly sandy in upper 0.3 m
0.8-1.0 m clayey silt showing vague coloured laminae, contains a single layer (approximately 1 cm) of buff coloured slightly sandy silt.

Field Station #6

Hand auger hole

0-1.1 m silty clay, uniform, no evidence of laminations but consistency indicates lacustrine origin, contains occasional siltstone and sandstone pebbles in lower 0.5 m.

Field Station #7

Previously dug test pit

The present bottom extends to 5.8 m. Spoil pieces consist of firm clayey silt to silty clay. Material is vaguely laminated and contains occasional pebbles. Narrow grain size range and low pebble content suggests lacustrine origin.

Field Station #8

Hand auger hole

0-1.1 m mottled grey silty clay containing occasional grit

Mr. Norman Vaughan indicates that he has found stones at 0.9 m. Several pebbles and cobbles were noted down to 0.2 m along the fence row. These had been exposed during ploughing in the spring.

Field Station #9

Previously dug back hoe test pit left open. The test pit was flooded beneath 1.4 m and Mr. H. Black and Mr. N. Vaughan indicated the total depth to be 2.7 m. Spoil pile from the bottom of the hole indicates clayey silt with some interbedded medium sand. Visible portion of pit wall contains:

0-0.2 m black silty topsoil

0.2-1.4 m mottled brown clayey silt, weathered

Field Station #10

Hand dug test pit at location of spring in hillside

0-0.8 m brown silty clay to clayey silt, weathered

0.8-1.0 m brown silty clay with sand seams, sand seams are 0.5-1.5 cm thick and contain water, water slowly filling bottom of hole on completion

Field Station #11

Hand dug test pit

0-0.9 m brown silty clay with fine sand interbeds, weathered

Field Station #12

Previously dug backhoe test pit (filled in) soil description by H. Black

0-0.9 m	brown silty clay to clayey silt, sand seams (to 0.5 cm) in base of pit, sand saturated

Field Station #13

Hand auger hole

0-0.2 m	dark brown silt topsoil
0.2-0.8 m	red brown silt
0.8-2.7 m	medium brown to red brown silt, contains trace of clay and very fine sand
2.7-3.2 m	medium brown to red brown silty very fine sand, saturated contains trace of clay
3.2-3.5 m	grey brown silty clay with some mottling, contains trace of sand

Field Station #14

Hand auger hole

0-1.4 m	clayey fine gravel

A seepage area with dirty gravel at surface was noted just to the west of the test hole

Field Station #15

Hand auger hole located on edge of depression (about 6 m from its centre)

0-1.1 m	weathered clayey silt with sandy zones in lower 0.5 m

Material was difficult to identify due to the extensive weathering and disturbed nature of the sample from augering.

Field Station #16

Hand auger hole

0-0.3 m	dark brown silty clay

Field Station #17

Hand auger hole

0-0.2 m	brown sand
0.2-0.3 m	reddish brown silty clay

Field Station #18

Hand auger hole

0-0.8 m	brown sand, contains some small pebbles (<5 mm)

Field Station #19

Hand auger hole

0-0.6 m	brown sand contains occasional small pebbles (<5 mm)
0.6-1.1 m	dark grey brown silty clay, shows reddish brown weathered stains, contains minor sand stringers about 1 mm thick

Field Station #20

Hand auger hole

0-1.1 m	mixed clayey silt, silt and fine sand, appears laminated near bottom of hole.

Field Station #21

Hand auger hole

0-0.9 m	brown clay
0.9-1.1 m	brown clay, contains thin sand and gravel stringers. Water was noted at 0.3 m.

8.5 GARTNER LEE ASSOCIATES LIMITED BOREHOLE LOGS, 1984

Borehole locations are shown in Figure 4 (in map pocket).

Borehole logs are based on field notes which have been verified by the project geologist following examination of samples.

Continuous samples were obtained by advancing a large split tube (8.9 cm x 152 cm) through the hollow stem augers.

Standard penetration tests were performed at 1.5 m intervals and water contents were measured in samples taken from the 'nose-piece' of the standard split spoon sampler.

Textural descriptions are provided for each geologic unit and each unit is named (in brackets) to indicate its origin.

All material descriptions are based on visual hand sample examination and no laboratory grain size analyses were performed. Textural descriptions are provided under follow a 'Particle Size Classification System' in the Glossary of Selected Terms, Section 8.7.

Borehole elevations are estimated from the 1:10000 scale base map elevation contours. All elevations are above sea level (ASL) and are estimated to the nearest metre.

The term pebble has been used to describe gravel sized rock particles within a fine grained soil matrix.

GEOTECHNICAL NOTES AND ABBREVIATIONS

Standard Penetration Resistance 'N' - The number of blows required to advance a standard split spoon sampler 30 cm into the subsoil, driven by means of a 63.5 kg hammer falling freely a distance of 75 cm.

The consistency of cohesive soils and the relative density or denseness of cohesionless soils are described as follows:

Consistency	'N' Blows per 0.3 m	Denseness	'N' Blows per 0.3 m
Very soft	0-2	Very Loose	0-4
Soft	2-4	Loose	4-10
Firm	4-8	Compact	10-30
Stiff	8-15	Dense	30-50
Very Stiff	15-30	Very Dense	> 50
Hard	> 30		

ABBREVIATIONS

WTPL - Wetter than Plastic Limit

DTPL - Drier than Plastic Limit

APL - About Plastic Limit

Wp - Plastic Limit

WL - Liquid Limit

SS - Split Spoon Sample

T - Split Tube Sample

BOREHOLE NO. GL 1 (3C)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** August 14/84

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 179 m (approximately) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % COMMENTS (10 20 30; Wp, Wl)
0.3	TOPSOIL: dark brown silty clay topsoil, with roots								
	SILTY CLAY TO CLAYEY SILT: brown to dark greyish brown silty clay to clayey silt, generally well laminated with occasional massive zones, red and grey laminations, occasional small (<1 cm) pebble heavily weathered and fractured in upper ±1 m, stiff to very stiff, DTPL to 2.7 m, APL 2.7 to 7.2 m, WTPL below 7.2 m (Upper Glaciolacustrine Unit)			1	SS	26	21		
				2	SS	28	24		
				3	SS	21	29		
	fracture with calcite crystals (6.0 m)			4	SS	18	33		
	approximate level of brown/grey colour change ±6.5 m			5	SS	10	32		
	brown discolouration along fracture at 9.2 m			6	SS	13	30		
	8 cm inclusion of brown silt till at 9.4 m			7	SS	11	33		
	- increased number of pebbles 11.8 to 12.1 m			8	SS	10	32		
				9	SS	10	31		
				10	SS	11	38		
				11	SS	11	33		
	- occasional silt lamina to 2 mm thick 17.3 to 18.3 m			12	SS	13	41		
20.0				13	SS	9	32		
	SILTY CLAY TO CLAYEY SILT TILL: brown silty clay to clayey silt till, generally massive with indistinctly laminated zones, upper and lower contacts are gradational, 6 cm thick layer of silt to silty fine sand at 20.5 m, very stiff, WTPL (Halton Till)			14	SS	19	23		
				15	SS	27	23		
25.0				16	SS	20	22		

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BOREHOLE NO. GL 1 (3C) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** August 24, 1985

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 179 m (approximately) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) COMMENTS
26.3	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, laminated, occasional small pebbles (<1 cm), stiff to very stiff, WTPL (Lower Glaciolacustrine Unit)			17	SS	15	20		
28.5	FINE SAND: brown fine sand with pebbles, saturated, very dense (Lower Glaciolacustrine Unit)			19	SS	*	5.5	* 99/0.15 m	
30.5	SANDY SILT TILL: brown sandy silt till, saturated, very dense (Lower Till)			20	SS	71	13		
	Borehole terminated at 30.5 m in till								

Gartner Lee Associates Limited

BOREHOLE NO. GL 2 (3C)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** August 18, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 180 m (approximately) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) COMMENTS
0.5	TOPSOIL: dark brown clayey silt topsoil, roots								
	- fracture with gypsum crystals (1.8 m)			1	SS	32	23		
				2	SS	15	30		
	- material becoming massive (±4.2 m)			3	SS	14	25		
	SILTY CLAY TO CLAYEY SILT: pale brown to dark greyish brown silty clay to clayey silt, well laminated with occasional massive zones, grey and red laminations, occasional small (<1 cm) pebble, firm to hard, APL to 2.7 m, WTPL 2.7 m to 20.4 m (Upper Glaciolacustrine Unit)			4	SS	10	34		
				5	SS	7	36		
	material becoming laminated, occasional thin discontinuous silt lamina to 2 mm			6	SS	7	37		
				7	SS	9	39		
	occasional silt lamina to 2 mm			8	SS	10	35		
				9	SS	11	39		
15.5				10	SS	9	33		
	CLAYEY SILT TO SILTY CLAY TILL: dark yellowish brown clayey silt to silty clay till, massive, gradational upper and lower contacts, stiff, WTPL (Halton Till)			11	SS	12	28		
18.0				12	SS	11	24		
	SILTY CLAY TO CLAYEY SILT: brownish grey silty clay to clayey silt, decreasing pebble content and clearer laminations with depth, stiff, WTPL (Lower Glaciolacustrine Unit)			13	SS	8	11		
20.4				14	SS	*	7	* 47/0.15 m	
	SANDY SILT TILL: dark yellowish brown sandy silt till, very dense, saturated (Lower Till)			15	SS	85	6		
24.8	Borehole Terminated at 24.8 m in till								

Wp — Wl

Gartner Lee Associates Limited

BOREHOLE NO. GL 3 (3C)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** August 14, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 179 m (approximately) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.5	TOPSOIL: dark brown silt topsoil, roots								
	occasional silt lamina to 1 mm, 1.6 to 2.4 m			1	SS	33	25		
	SILTY CLAY TO CLAYEY SILT: brown to dark greyish brown silty clay to clayey silt, well laminated with occasional massive zones, grey and red laminations, occasional small (<1 cm) pebble, heavily weathered to 1.3 m, firm to hard, DTPL 0 to 1.5 m, APL 1.5 to 3.0 m, WTPL below 3.0 m (Upper Glaciolacustrine Unit)			2	SS	19	28		
				3	SS	27	26		
				4	SS	17	35		
	fracture with calcite crystals 5.8 m								
	subtle colour change (dark greyish brown to brown) ±7.0 m			5	SS	8	37		
				6	SS	10	28		
				7	SS	13	34		
	massive to well laminated			8	SS	12	38		
	well laminated with occasional silt lamina to 3 mm			9	SS	12	32		
				10	SS	9	39		
17.0	increasing sand and pebble content below 16.2 m			11	SS	5	38		
	SILTY CLAY TO CLAYEY SILT TILL: brown silty clay to clayey silt till, massive with indistinctly laminated zones, upper and lower contacts are gradational, 4 cm thick inclusion of sandy silt till at 18.5 m, stiff, WTPL (Halton Till)			12	SS	11	28		
				13	SS	10	27		
20.9	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, occasional small (<1 cm) pebbles becoming well laminated with depth, firm to stiff, WTPL (Lower Glaciolacustrine Unit)			14	SS	8	41		
22.6	STONY SANDY CLAYEY SILT TILL: grey sandy clayey silt till, hard (Lower Till)			15	SS	45	9		
23.1	DOLOMITIC SHALE: grey dolomitic shale, fine bedded, occasional gypsum nodule (Salina Formation)								
24.7	Borehole Terminated at 24.7 m in shale.								

Gartner Lee Associates Limited

BOREHOLE NO. GL 4 (3C)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** August 16/84

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 180 m (approximately) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
0.4	TOPSOIL: dark brown silt topsoil, roots								
				1	SS	33	22		
				2	SS	26	32		
				3	SS	24	24		
	fracture with calcite crystals 5.0 to 5.8 m								
				4	SS	10	34		
	SILTY CLAY TO CLAYEY SILT: dark brown to dark grey silty clay to clayey silt, well laminated with occasional massive zones, grey and red laminations, occasional small pebble to 1 cm, heavily weathered to 1.1 m, stiff to hard, DTPL 0 to 2.7 m, APL 2.7 to 4.2 m, WTPL below 4.2 m, subtle colour change brown to grey at approximately 5.5 m (Upper Glaciolacustrine Unit)			5	SS	9	32		
				6	SS	8	33		
				7	SS	9	36		
				8	SS	9	36		
				9	SS	8	36		
				10	SS	9	36		
	occasional silt lamina to 1 mm 8 cm silt bed at 15.7 m								
				11	SS	9	42		
18.0									
	SILTY CLAY TO CLAYEY SILT TILL: brown silty clay to clayey silt till, generally massive with indistinctly laminated zones, upper contact gradational, lower contact sharp, stiff to very stiff, WTPL (Halton Till)			12	SS	14	19		
				13	SS	18	18		
20.7									
	INTERBEDDED SILT AND CLAY: Interbedded brown silty clay, sandy silt and laminated silty clay with pebbles, interbeds are 0.1 m to 0.5 m thick (Lower Glaciolacustrine Unit)			14	SS	12	15		
				15	SS	26	9		
24.0									
	SILTY CLAY: dark greyish brown silty clay, occasional pebble, hard, WTPL (Lower Glaciolacustrine Unit)			16	SS	39	23		
25.0									

Gartner Lee Associates Limited

BOREHOLE NO. GL 4 (3C) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** August 16 , 1985

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 180 m (approximately) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
26.0	SANDY SILT TILL: dark grey sandy silt till, very dense, saturated (Lower Till)			17	SS	*	9	* 55/0.08 m →	
26.9	DOLOSTONE: mottled grey medium to coarse grained dolostone, banded, small vugs (Guelph Formation)								
	Borehole terminated at 26.9 m in dolostone								

BOREHOLE NO. GL 5 (3C)

PROJECT NAME Phase 4A ,Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** August 21, 1985

BOREHOLE TYPE 108 mm ID Hollow Stem Auger ,Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 180 m (approximately) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
0.3	TOPSOIL: dark yellowish brown clayey silt, roots								
	SILTY CLAY TO CLAYEY SILT: brown to dark grey silty clay to clayey silt, well laminated with occasional massive zones, grey and red laminations, occasional small (<1 cm) pebbles, heavily weathered to 1.1 m, occasional fine sand lamina (to 1 cm thick) to 1.7 m depth, stiff to very stiff, DTPL 0 to 2.7 m, APL 2.7 to 3.0 m, WTPL 3.0 to 26.1 m (Upper Glaciolacustrine Unit)			1	SS	25	21		
				2	SS	29	25		
				3	SS	15	32		
				4	SS	14	26		
				5	SS	13	32		
	four fractures, 8.7 m, 9.8 m, 11.0 m, 12.0 m with carbonate infilling and brown discolouration			6	SS	10	28		
				7	SS	10	28		
				8	SS	13	28		
	occasional silt lamina to ± 1 mm			9	SS	8	36		
				10	SS	10	35		
				11	SS	10	29		
19.5	small pebble (<1 cm) content increasing			12	SS	10	43		
	SILTY CLAY TO CLAYEY SILT TILL: brown silty clay to clayey silt till, massive with indistinctly laminated zones, massive below 20.9 m, gradational upper boundary, stiff to hard, WTPL (Halton Till)			13	SS	10	25		
				14	SS	15	25		
				15	SS	17	19		
25.0				16	SS	32	24		

Gartner Lee Associates Limited

BOREHOLE NO. GL 5 (3C) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE August 21, 1985

BOREHOLE TYPE 108 mm ID Hollow Stem Auger , Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 180 m (approximately) PROJECT NO. 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) Wp Wl COMMENTS
26.2	SILTY CLAY TO CLAYEY SILT: dark yellowish, brown silty clay to clayey silt, laminated, occasional small (<1 cm) pebble, stiff, WTPL (Lower Glaciolacustrine Unit)			17	SS	13	38		
	SILTY SAND TILL: dark greyish brown silty sand till, very dense, saturated (Lower Till)			18	SS	*	5	* 50/0.15 m	
	NOTE: poor sample recovery ± 24 to 31 m			19	SS	*	7	* 50/0.15 m	
31.4									
33.5	DOLOSTONE: grey medium to fine grained dolostone, medium to fine bedded, banded, occasional small vug (Guelph Formation)								
	Borehole terminated at 33.5 m in dolostone								

8.6 SUPPORTING CALCULATIONS AND METHODS
VERTICAL GROUND WATER FLOW

In 1856, the French hydraulics engineer Henry Darcy reported that flow through a porous medium is proportional to the head loss and inversely proportional to the distance travelled. The formulation of these relationships is called Darcy's Law and may be written as specific discharge (v) = hydraulic conductivity (K) x gradient (i). The specific discharge is the total discharge per unit area of the discharging porous medium and does not indicate the velocity of the water 'particles'. The velocity of the water (average linear velocity, $\bar{v}$) may be obtained by dividing the specific discharge (v) by the effective porosity (n) of the porous medium. Because effective porosity is always less than 1, the average linear velocity ($\bar{v}$) is always greater than the specific discharge (v).

$$\text{Average Linear Velocity } (\bar{v}) = \frac{\text{hydraulic conductivity (K) x gradient (i)}}{\text{effective porosity}}$$

Lateral Ground Water Flow

Once the above parameters are known for a porous medium, an average linear velocity may be calculated. The following example utilizes values typical of lateral flow in the fractured zone:

- hydraulic conductivity (K) 1×10^{-8} m/s
- lateral gradient (i) 0.003
- effective fracture porosity 0.0001

$$\bar{v} = \frac{Ki}{n} = \frac{1 \times 10^{-8} \times 0.003}{0.0001} = 3 \times 10^{-7} \text{ m/s or } \approx 10 \text{ m/year.}$$

Vertical Ground Water Flow

The application of Darcy's Law to ground water flow through layered porous media when the layers have differing thicknesses and hydraulic properties is discussed in Freeze and Cherry (1979) and is summarized below with regard to the area under study. The layered porous media of interest are the confining layer subunits which usually include the fractured zone; the unfractured zone and the lower till. Estimating the rates of ground water flow in each of these layers involves (1) the calculation of a single equivalent hydraulic conductivity for the three layers, (2) calculation of the specific discharge through the layers and (3) the calculation of average linear velocities in each of the layers.

The calculation of an equivalent hydraulic conductivity (Ke) for the three-layer situation is:

$$Ke = \frac{d(FCL + CL + LT)}{\frac{dFCL}{KFCL} + \frac{dCL}{KCL} + \frac{dLT}{KLT}}$$

where K and d are the hydraulic conductivity and thickness respectively and the subscripts are e (equivalent), FCL (fractured confining layer), CL (confining layer) and LT (lower till).

The calculation of specific discharge (v) uses the equivalent hydraulic conductivity (Ke) and the overall vertical gradient (i) across the layers in Darcy's Law:

$$v = Ki$$

And finally, the average linear ground water velocity ($\bar{v}$) in each layer is obtained by dividing the specific discharge (v) by the effective porosity (n) for each of the layers involved.

The following example uses numbers similar to those in the report (values relate to the layers identified above; thicknesses are in m and hydraulic conductivities are in m/s).

$$Ke = \frac{23.1}{\frac{5}{1\times10^{-8}} + \frac{17.6}{3\times10^{-10}} + \frac{0.5}{1\times10^{-8}}} = \frac{23.1}{5.9\times10^{10}} = 3.9\times10^{-10} \text{ m/s}$$

where the vertical gradient (i) is 0.2:

$$v = Kei = 3.9 \times 10^{-10} \times 0.2 = 7.8 \times 10^{-11} \text{ m/s}$$

$$\text{or } 2.5 \times 10^{-3} \text{ m/year}$$

The average linear velocity ($\bar{v}$) = specific discharge divided by effective porosity for each individual layer.

For the fractured confining layer, effective porosity (n) = 0.0001 and the average linear velocity ($\bar{v}$) =

$$7.8 \times 10^{-11} / .0001 = 7.8 \times 10^{-7} \text{ m/s or } \sim 25 \text{ m/year}$$

For the unfractured confining layer, no effective porosity value is available and consequently a total porosity value of 0.5 is used to calculate an average linear velocity ($\bar{v}$) = $7.8\times10^{-7}/0.5$ =

$$1.6\times10^{-10} \text{ m/s}$$

$$\text{or } 5.0\times10^{-3} \text{ m/year}$$

For the lower till, no effective porosity value is available and consequently a total porosity value of 0.3 is used to calculate an average linear velocity: $7.8 \times 10^{-11}/0.3$

$= 2.6 \times 10^{-10}$ m/s

or 8.2×10^{-3} m/year.

(These are approximate values and are usually rounded to one significant figure in the text).

The major assumptions for these calculations are:

(1) flow is steady state,
(2) flow is in a direction perpendicular to the layering,
(3) layers are homogeneous and isotropic,
(4) flow is governed by Darcy's Law. A more complete and theoretical discussion is given in Freeze and Cherry (1979).

For a more accurate discussion of ground water flow rates in the confining layer based on advection and diffusion calculations, the reader is referred to Appendix A of the report entitled "Site Selection Process, Phase 4A; Selection of Preferred Site(s), Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

8.7 GLOSSARY OF SELECTED TERMS

8.7 GLOSSARY OF SELECTED TERMS

Alluvium
Sediment composed of organic material, clay, silt, sand, gravel cobbles, or boulders deposited by postglacial streams. (2)

Aquifer
A body of sediment (or rock) that contains sufficient saturated permeable material to conduct ground water and yield economically significant quantities of ground water to wells and springs.(2)

Bearing Pressure (Allowable)
Means the maximum pressure that may be safely applied to a soil or rock by the foundation unit in design under expected loading and subsurface conditions. (8)

Confining Bed (Layer)
A body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers. (1)

Darcy's Law
For the velocity of percolation of water in saturated soil is: Velocity = coefficient of permeability x hydraulic gradient. (4)
(hydraulic conductivity is used in place of coefficient of permeability in this report).

Desiccated Crust
The exposure of fine-grained sediments to drying is accompanied by shrinkage and possibly cracking. Precompression of the upper portions of clay layers by drying is frequently observed in many of the profiles encountered in practice. The effects of desiccation are an increase in strength and a decreased water content. (6)

Drawdown
The lowering of the water level in a well as a result of withdrawal. (1)

Drift
A general term applied to all rock material (clay, silt, sand, gravel, boulders) transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier. (1)

Evaporite
A nonclastic sedimentary rock composed primarily of minerals produced from a saline solution as a result of extensive or total evaporation of the solvent. Examples include: gypsum, anhydrite, rock salt, primary dolomite, and various nitrates and borates. (3)

Geometric Mean
The nth root of the product of the values of n positive numbers; the antilogarithm of the mean of the logarithms of individual values. (1)

Geotechnical, Geotechnics
Pertaining to the broad field of geotechnics. The application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust for the solution of engineering problems. (1)

Glacial Lake
A lake fed predominantly by glacial meltwater or a lake in a depression in part closed by glacial ice. Includes lakes not directly adjacent to the glacier and lakes lying against or on a glacier, and fed mainly by waters derived from the melting of a glacier. (2)

Glaciofluvial
Pertaining to streams flowing from glaciers or to the deposits made by the streams. (2)

Glaciolacustrine
Pertaining to or characterized by glacial and lacustrine (lake) conditions. Material deposited in lakes affected by glacier ice, or deposited by meltwater flowing directly from glaciers into a lake. (2)

Ground Water
Subsurface water occurring below the water table (phreatic surface) in the saturated zone in which all pores are filled with water under hydrostatic pressure. This contrasts with subsurface water above the water table, which is referred to as soil moisture. (2)

Grout
A cement slurry of high water content, fluid enough to be poured or injected into spaces and thereby fill or seal them. (1)

Hardness (Water)
A property of water causing formation of an insoluble residue when the water is used with soap, and forming a scale in vessels in which water has been allowed to evaporate. It is primarily due to the presence of ions of calcium and magnesium, but also to ions of other alkali metals, other metals (e.g. iron), and even hydrogen. Hardness of water is generally expressed as parts per million as $CaCO_3$ (40 ppm Ca produces a hardness of 100 ppm as $CaCO_3$); also as milligrams per litre, and is the combination of carbonate hardness and noncarbonate hardness. (1)

Hazardous Waste
Waste that poses a present or potential danger to human beings or other organisms because it is toxic, flammable, radioactive, explosive, or has some other property that produces substantial risk to life. (1) (Use here excludes radioactive waste)

Heave
A predominantly upward movement of a surface, caused by expansion or displacement, as from swelling clay, removal of overburden, seepage pressure, or frost action. (1)

Hydraulic Gradient
In an aquifer, the rate of change of total head per unit of distance of flow at a given point and in a given direction. (1)

Hydraulic Head
The height of the free surface of a body of water above a given subsurface point. (1)

Hydraulic conductivity
The proportionality factor in Darcy's law as applied to the viscous flow of water in soil, that is, the flux of water per unit gradient of hydraulic potential. (3)

Hydrogeology
The science that deals with subsurface waters and with related geologic aspects of surface waters. (1)

Hydrostratigraphic Unit
A term proposed by Maxey (1964, p. 126) for a body of rock having considerable lateral extent and composing "a geologic framework for a reasonably distinct hydrologic system". (1)

Infiltration
The flow of a fluid into a solid substance through pores or small openings; specifically the movement of water into soil or porous rock. (1)

Lamina
The thinnest recognizable unit layer of original deposition in a sediment or sedimentary rock, differing from other layers in colour, composition, or particle size; specifically such a sedimentary layer less than 1 cm in thickness (commonly 0.05-1.00 mm thick). (1)

Log
A continuous record as a function of depth, usually graphic and plotted to scale on a narrow paper strip, of observations made on the rocks and fluids of the geologic section exposed in a well bore. (1)

Moraine
Accumulation of glacial material (mainly till) deposited by glaciers. (2)

Particle Size Classification System (9)

Name	Qualifying Term	Approximate Particle Size (mm)
Boulders		<200
Cobbles		60-200
Gravel	(Pebble)	2-60
Sand	Coarse	0.6-2
	Medium	0.2-0.6
	Fine	0.06-0.2
Silt		0.002-0.06
Clay		<0.002

Permeability
The capacity of a porous medium to transmit a liquid or gas subjected to an energy gradient (in the case of water, hydraulic gradient). (2)

Porosity
The ratio of the volume of voids to the total volume of a soil sample. (4). Effective porosity is the amount of interconnected space available for field transmission (3).

Quaternary
The youngest period of the two geologic time divisions of the Cenozoic Era. The Quaternary is subdivided into the Pleistocene and Recent (or Holocene) Epochs. It comprises all geologic time and deposits from the end of the Tertiary (approximately 2 million years ago) until and including the present. (2)

Saturated
Said of the condition in which the interstices of a material are filled with a liquid, usually water. It applies whether the liquid is under greater than or less than atmospheric pressure, so long as all connected interstices are full. (1)

Settlement
Downward movement of a structure such as a railway bridge, dam, or building, due to compression or movement of the soil below it. (4)

Shear Strength
The internal resistance offered to shear stress. It is measured by the maximum shear stress, based on original area of cross-section, that can be sustained without failure. (5)

Two extreme conditions may be recognized: drained conditions, under which the changes in stress are applied so slowly with respect to the ability of the soil to drain that no excess pore pressures develop, and undrained conditions, under which the stresses are changed so rapidly with respect to the ability of the soil to drain that no dissipation of pore pressure takes place. (7)

Slug Test
A method of determining in situ hydraulic conductivity in a single piezometer by causing an instantaneous change in the water level by adding or displacing a known volume of water. (10)

Split Spoon Sampler
Sampling spoons for exploratory borings commonly consist of a pipe with an inside diameter of about 35 mm and an outside diameter of about 51 mm. The pipe is split lengthwise. Consequently the sampler is called a split spoon. While the sample is being taken, the two halves of the spoon are held togther at the ends by short pieces of threaded pipe. One piece serves to couple the spoon to the wash pipe. The other, which has been sharpened, serves as the cutting edge while the spoon is driven into the soil. Exact dimensions are designated in ASTM DI586-67. (7)

Static (Water) Level
That water level of a well that is not being affected by withdrawal of ground water. (1)

Stratigraphic Unit
A stratum or body of adjacent strata recognized as a unit in the classification of a rock sequence with respect to any of the many characters, properties, or attributes that rocks may possess. (1)

Surcharge Load
A weight per unit of area of fill great enough to consolidate the soil sufficiently to increase its strength or reduce its compressibility to the required extent within the time available. Compressible soils such as clays, loose silts, and most organic soils may be compacted by surcharging. (7)

Till
An unsorted mixture of clay, silt, sand, pebbles, cobbles and boulders deposited directly by glacier ice. (2)

Water Table
A surface in the saturated zone below ground level along which the hydrostatic pressure is in equilibrium with the atmospheric pressure. (2)

Weathering
The destructive process or group of processes by which earthy and rocky materials on exposure to atmospheric agents at or near the earth's surface are changed in colour, texture, composition, firmness, or form with little or no transport of the loosened or altered material; specifically, the physical desintegration and chemical decomposition of rock that produce an in situ mantle of waste and prepare sediments for transportion. (1)

SOURCES

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8.8 DETAILED FIELD METHODS

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8.8.1. INTRODUCTION

Field data for of the Phase 4A hydrogeologic onsite investigations were collected in a standardized fashion and formed part of the basis for geologic, hydrogeologic, and geotechnical comparisons of the eight candidate sites. An outline of the major field activities is shown in Figure 9. The study approach was modified only slightly on a site-by-site basis to accommodate differing circumstances and site conditions. Standard procedures for the drilling and sampling operations, as outlined in the Gartner Lee Associates Ltd. "Drilling and Sampling Protocol" document (GLAL 1984a), were adhered to throughout the drilling program. This protocol document provides examples of field forms used to document field activities and should be referred to for more detailed drilling and sampling procedural descriptions.

DETAILED FIELD METHODS

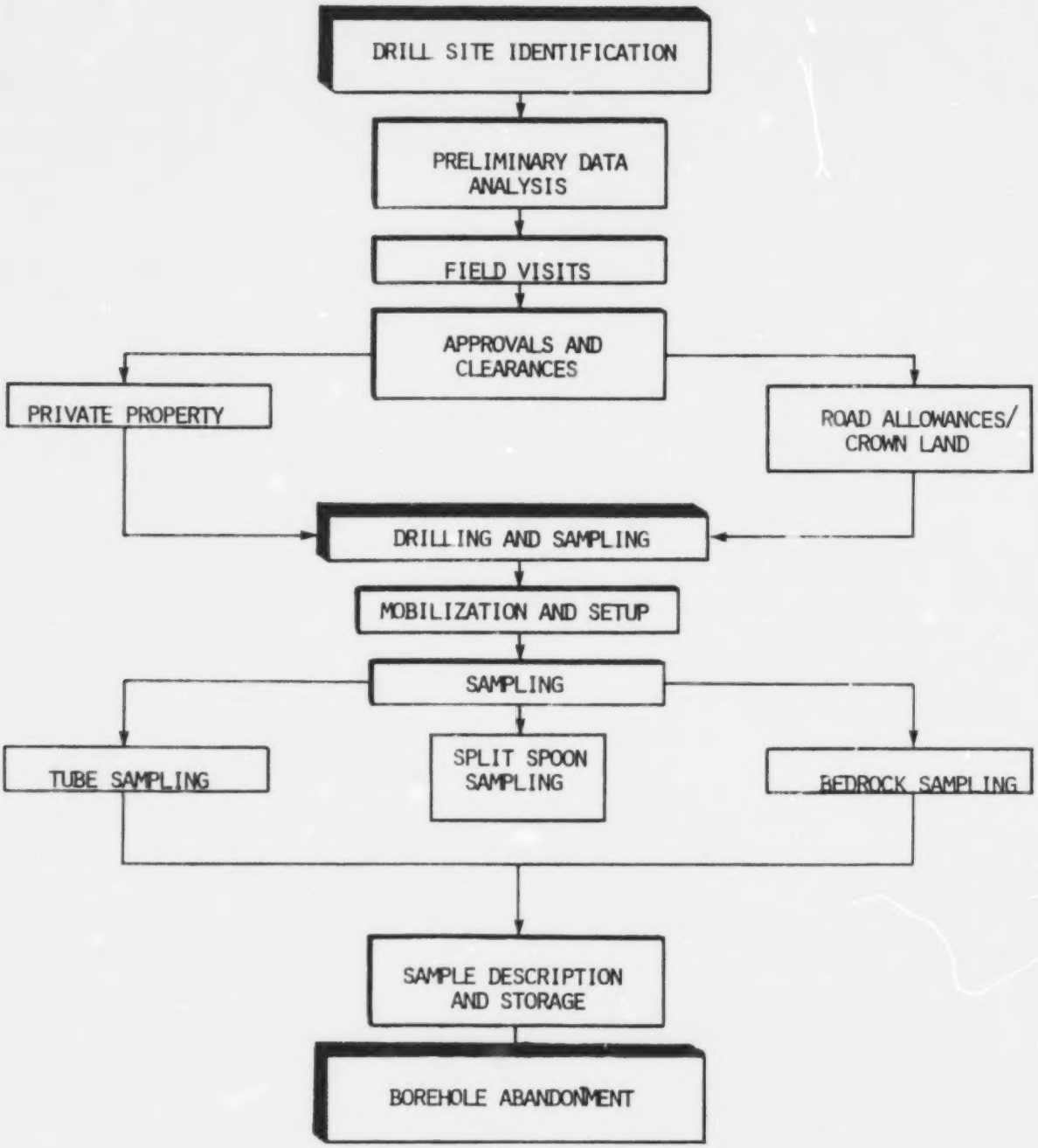


Figure 9

8.8.2 DRILL SITE IDENTIFICATION

8.8.2.1 Preliminary data analysis

A preliminary review of existing water well and test hole data was completed to establish a basis for the selection of tentative drill locations. Criteria used included the following:

- the distribution of existing test holes and water wells;
- the continuity of existing data; and
- anomalous or unusual site conditions.

While locations were selected primarily on technical grounds, practical considerations such as site access, potential crop damage, and landownership were also taken into account.

8.8.2.2 Field visits

The concerns of local public interest groups and individuals were also considered in selecting drill locations. Local interest groups were invited to participate during field checking of the drill locations. During these field visits, additional data on water use, local soil conditions, and wells were obtained from local residents. This information was used as a check on some of the field data obtained previously by Ecolgistics Limited during the 1984 "Walk and Talk" survey. The amount of information thus obtained varied from site-to-site and depended largely upon the degree of co-operation given by residents and landowners.

A limited amount of soil probing was completed at Candidate Sites LF-3C, LF-9C, and PI-13N using a 25 mm (1 inch) magnesium hand auger. These investigations were generally

limited to a depth of 1 to 2 m. Hand augering was directed toward areas of suspected granular soils or anomalous soil conditions identified by local residents. Soil probing was confined to areas where property access was permitted. Soil descriptions are included under "Field Station Descriptions" in the individual technical site reports.

The tentative drill locations were adjusted during the field visits to avoid difficult or unsafe drilling locations. Each location was marked with a temporary wooden stake. Final adjustments were subsequently made, where necessary, to provide the required safe setbacks from buried and overhead services.

8.8.2.3 Approvals and Clearances

Clearances for both road allowances and adjacent private or public property were pursued where identified drilling locations were located in the vicinity of local roads. Road allowances were drilled where access to private property was denied.

Landowners and tenants of affected properties were initially contacted by GLAL and verbal approval for test drilling was obtained. Approval was confirmed with a follow up letter from OWMC. For road allowance clearances, the appropriate agencies were contacted and the necessary permit approvals were obtained.

Utilities were contacted and buried service cables and/or pipes were field located by utility personnel and final adjustments of drill locations were completed.

Drilling approvals and clearances were completed on a site-by-site basis.

8.8.3 DRILLING AND SAMPLING

8.8.3.1 Drilling equipment and setup

All Terrain Drilling Limited was retained to provide drilling services. The drilling equipment included truck and track mounted CME 75 auger drilling rigs. Two rigs were used simultaneously for most of the drilling program. Each rig was equipped to drill and sample both soils and bedrock. Each rig was staffed with a three man drilling crew and supervised by a GLAL geologist. The drilling program was initiated on August 13, 1984 at Site LF-3C and was completed on November 22, 1984 at Site LF-4N.

The drill rigs were set up in accordance with standard drilling practices and in a manner that allowed the safe and efficient operation of the equipment. A safety corridor was roped-off around the drill rig to limit access to the rigs. Access to the roped-off area was restricted to individuals with proper safety equipment which included steel-toed boots and a hard hat. A record was kept of all visitors to the drill site as well as persons entering the roped-off area.

Sample documentation and storage facilities were set up at the edge of the roped-off area by GLAL. Soil and rock samples were accessible to the general public for viewing and/or photographing as the samples were being logged by the onsite geologists. Samples were subsequently sealed in tubes or core boxes, labelled, and placed in storage. On several occasions, soil sample tubes were

re-opened for examination at the request of local residents.

8.8.3.2 Soil sampling

The drilling program was designed to obtain a continuous column of soil from the ground surface to and including the upper few metres of the underlying bedrock. Soil samples were obtained using hollow stem auger drilling techniques. Hollow stem augers (108 mm (4.25 inch) inside diameter) were used throughout the drilling program.

Split tube sampling. Tube samples measuring approximately 89 mm (3.5 inches) in diameter by 1.52 m (5 ft.) in length were taken continuously from ground level to the bedrock surface. The tube sampler consisted of a split tube with a bevelled sampler tip. The split tube was threaded at both ends and fastened to the drill rods as shown in Figure 10. The sampler as advanced inside the hollow stem augers with the bevelled tip slightly ahead of the cutting edge of the augers. A split tube sample was obtained by advancing the sampler with the rotating augers. The augers and sampler were advanced at about 1.52 m (5 ft.) intervals or until refusal, and the sampler was then withdrawn from the borehole. The soil sample was removed from the tube and the sampler washed with clean water. Sample recovery for the tube samples was generally between 90 to 100% and was recorded in the field log. Difficult drilling conditions or large cobbles occasionally resulted in lower sample recovery.

Split spoon sampling. Standard split spoon samples were taken at about 1.52 m (5 ft.) intervals throughout the soil sequence overlying bedrock and beginning at about 1.52 m

Continuous Soil Sampling With Split Tube Sampler

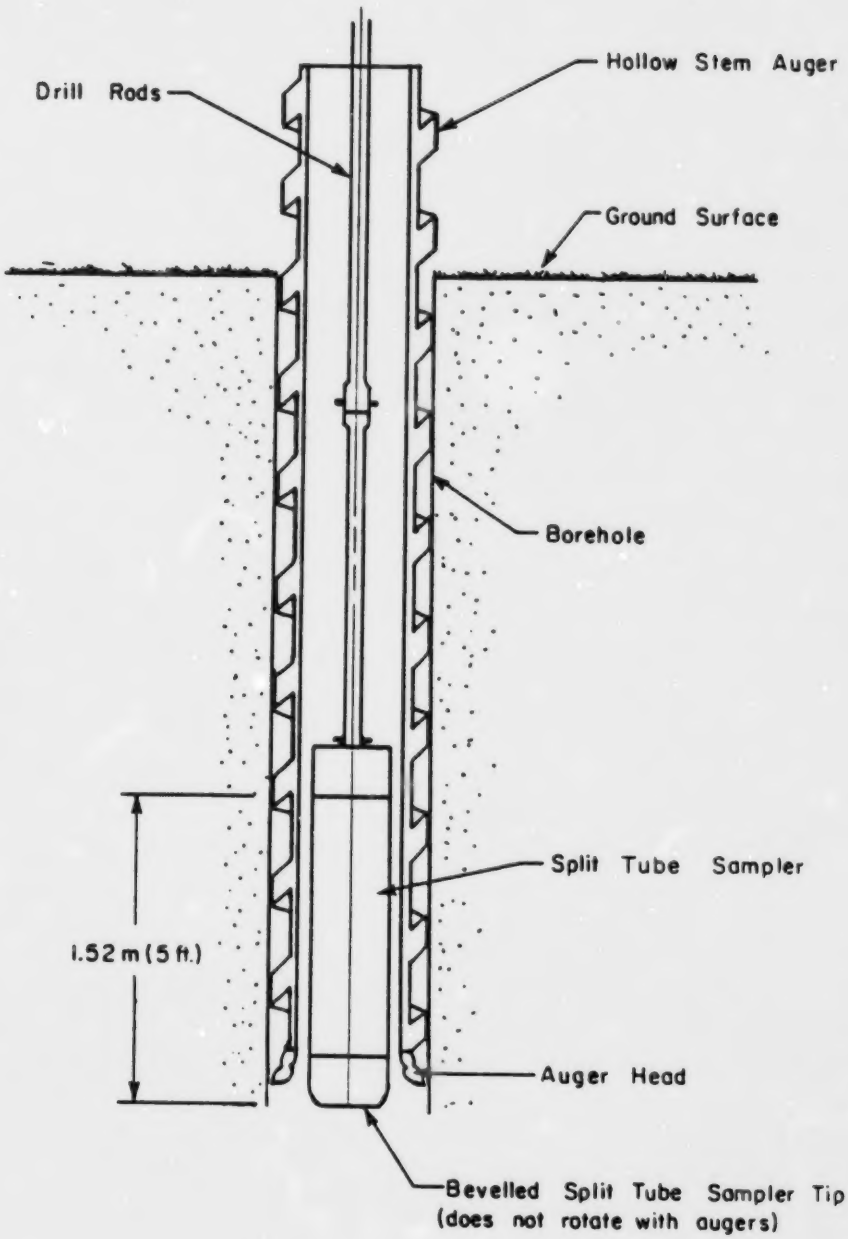


Figure 10

Soil & Rock Sample Intervals Phase 4A Drilling Program

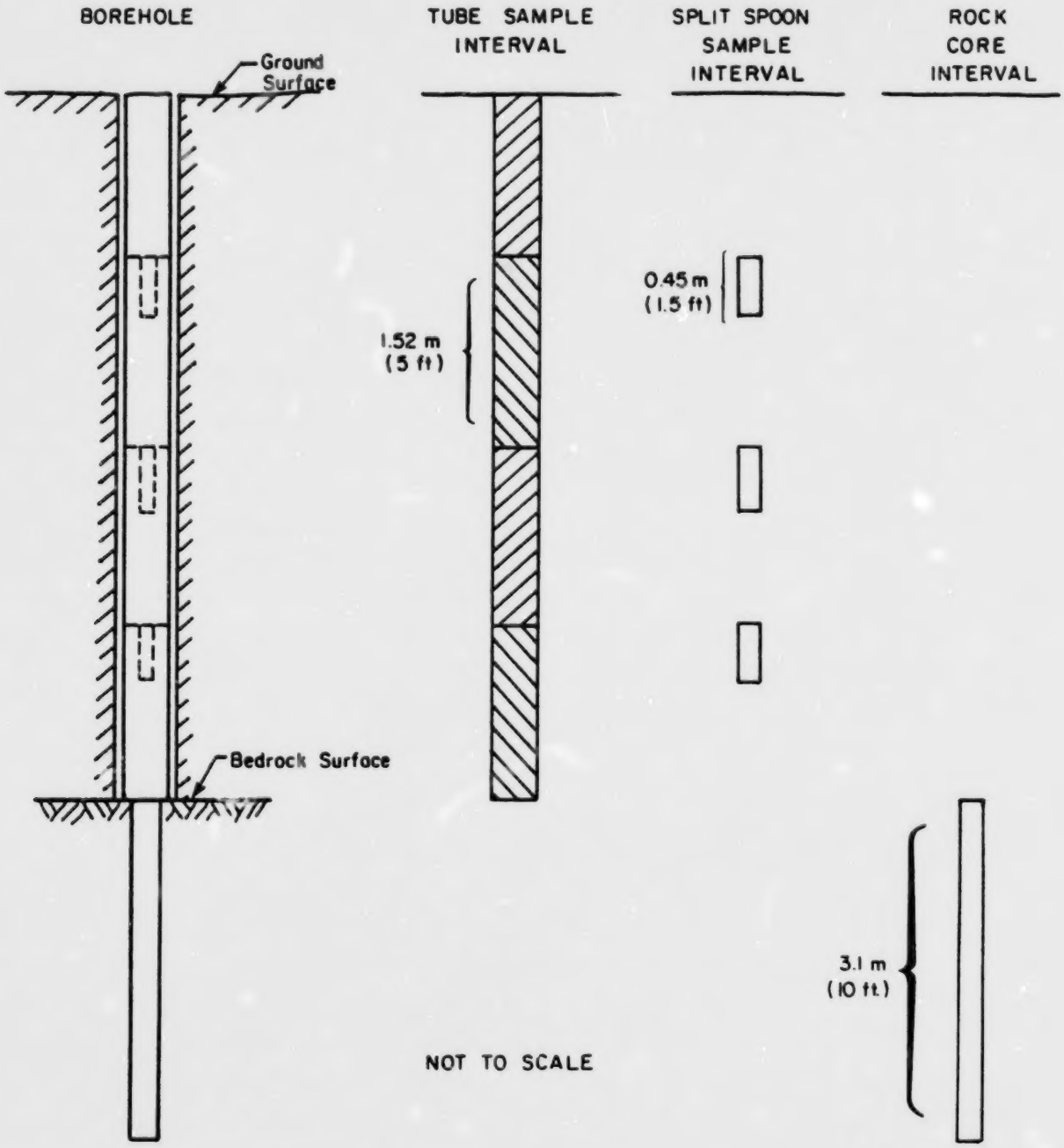


Figure 11

5 ft.) from the ground surface. Sample intervals are shown schematically in Figure 11.

The split spoon sampler was driven by dropping a 63.5 kg (140 lb.) weight a distance of about 750 mm (30 inches). The sampler was inserted inside the hollow stem augers in a similar fashion to the tube sampler. It was then driven into the soil below the bottom of the augers a distance of about 460 mm (18 inches) or until refusal. The number of blows required to advance the sample for each interval of about 150 mm (6 inches) was recorded in the field log. The split spoon was usually withdrawn when 50 or more blows were required to advance the sampler approximately 150 mm (6 inches) into the subsoil.

Standard split spoon samples were obtained in place of tube samples where difficult drilling conditions were encountered. At Site LF-4N, Borehole 4, granular soils were encountered at a depth of about 30 m (100 ft.) causing refusal of the tube sampler. Standard split spoon samples were taken from a depth of 30 m (100 ft.) at intervals of 0.5 to 3 m (1.6 to 9.8 ft.) to a depth of about 40 m (130 ft.). Difficult soil conditions were also encountered at Site LF-2N, Borehole 1. Numerous rock fragments were encountered below a depth of about 12 m (40 ft.) at this location. Split spoon samples at 0.76 m (2.5 ft.) intervals were taken between depths of about 12 m (40 ft.) to 34 m (110 ft.).

Difficult (sandy and gravelly) soil conditions at Site PI-27E, Borehole 3 prevented tube sampling between depths of about 16 to 30 m (50 to 100 ft.). Similar fine, sandy soils

were also encountered in Borehole 4 at this site at depths between approximately 24 to 30 m (80 to 100 ft.). Standard split spoon samples at 1.5 m (5 ft.) intervals were collected over these intervals at these two borehole locations.

Moisture tin samples. A small soil sample of approximately 100 grams was taken from the tip of each split spoon sample for laboratory determination of the soil moisture content. Soil moisture samples were placed in air tight tins immediately after they were taken from the split spoon samples. The moisture tin (sample) numbers were recorded on the field borehole logs. The samples were temporarily stored in the field and shipped in batches to the GLAL office for transfer to a commercial laboratory.

Rotary drilling. Rotary drilling techniques were occasionally used to penetrate difficult soils that could not readily be drilled with conventional hollow stem auger drilling methods. These techniques were also used where granular soils, acting under hydraulic pressures, were forced up inside the hollow stem augers. This condition prevented the split tube and split spoon samplers from passing through the plugged portions of the hollow stem augers. Clean water or a water/bentonite mixture was circulated through a rotating tricone drill bit to clean out the material in the hollow stem augers. Rotary drilling was also used to drill through gravelly or bouldery soils such as those encountered at depth at Site LF-4N, Borehole 4, and at Site LF-2N, Borehole 1.

8.8.3.3 Bedrock sampling

Boreholes were generally completed into bedrock except in a few cases where difficult drilling conditions were encountered and the borehole was terminated before reaching bedrock.

The bedrock contact was often obscured as a result of weathering, particularly in shale. Under conditions of extreme weathering, shale was occasionally retrieved within the split tube and split spoon samplers. For example, a nearly complete 1.5 m core of weathered bedrock was obtained in the split tube sampler in Borehole 5 at Site PI-13N.

Diamond drill coring. Most bedrock samples were obtained using a diamond drill bit and NX size core barrel. Rock core samples generally measured about 53 mm (2.1 inches) in diameter and up to 3 m (10 ft.) in length. The diamond drill bit and core barrel were positioned on the bedrock surface from inside the hollow stem augers. A rock core was obtained by the cutting action of the rotating drill bit. Clean water was circulated in the borehole to remove cuttings from around the drill bit. The water used in this operation was field checked with a Hach Kit for chlorides and sulphates to ensure compatibility with grouting materials used for borehole abandonment. The amount of water used was recorded on the field logs.

Bedrock coring was terminated when a sufficient length of sample was retrieved to prove-out the bedrock contact. The bedrock core recovered varied in length from about 1.5 m to 3 m (5-10 ft.) between borehole locations.

8.8.3.4 Sample description and storage

Soil and rock samples, taken from the boreholes, were described in detail in the field and photographed. Sample descriptions were recorded on the Field Borehole Log forms. These logs, together with the sample photos, form a permanent record of the sampling procedures.

The tube samples were transferred directly from the sampler into PVC tubular piping which was cut in half. The PVC pipe measures 89 mm (3.5 in.) inside diameter by 1.5 m (5 ft.) long. One 'side' of the sample was scraped clean along its length with a knife or spatula to facilitate sample description. Individuals and local interest groups were allowed to view the samples and make their own field notes of the samples. Soil scrapings were given to those interest groups that requested them or else were discarded. Soil samples were sealed in the PVC tubes by covering the ends with plastic caps and taping the entire tube along the seams. Sample labels were affixed to each PVC tube.

The samples were stored temporarily in a field van until a sufficient number of samples were obtained for transport to permanent storage facilities in Toronto at the Ontario Geological Survey. Each shipment of samples were itemized on a Sample Packing list. The contents of each shipment were also recorded on a Chain of Custody Record which showed the times and dates of sample transfer as well as the individuals involved in handling the samples.

Split spoon soil samples taken during the project were described in the field and soil moisture (moisture tin) samples taken from the base of the split spoon sampler were

submitted to a laboratory for analysis. The moisture tin number was recorded on the Field Borehole Log and on the Sample Packing List. In cases where a split spoon sample was taken in place of the larger split tube samples, they were stored in labelled plastic bags and retained with the other samples. The top of each bedrock core segment was marked on both the core boxes and on the rock core itself with a felt marker.

The soil and rock samples were re-examined by a senior GLAL geologist at the permanent storage area at the Ontario Geological Survey. The field descriptions were combined with the more detailed geologic log prepared by the senior geologist to compile a final borehole log. All soil samples were resealed after examination.

8.8.4 BOREHOLE ABANDONMENT

Boreholes were generally terminated after pentrating the bedrock or when difficult conditions prevented further drilling. An exception to this occurred at Site LF-1E, Borehole 3, where a gas pocket was encountered at a depth of about 17.8 m (58 ft.) in the drift. The borehole was terminated at this depth and sealed as soon as the gas pressure subsided sufficiently to allow grouting.

8.8.4.1 Grouting

On completion of each borehole all sampling equipment and temporary casing were removed from the borehole. Each borehole was then filled to the surface with a cement/ bentonite slurry. This was accomplished by injecting grout through the hollow stem augers as they were slowly withdrawn from the hole as shown in Figure 12. Specifi-

Grouting Of Borehole

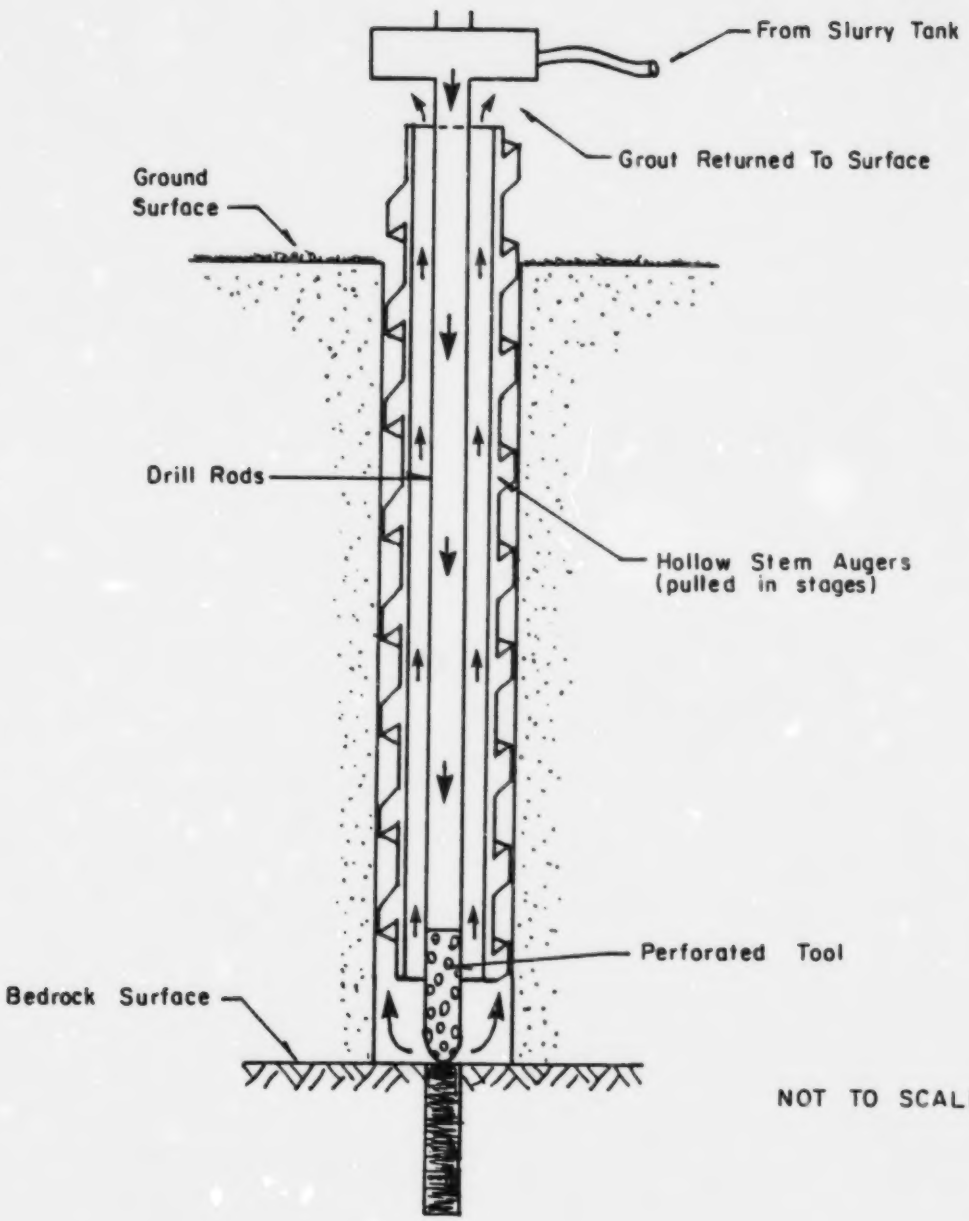


Figure 12

cations of the slurry mix, as set out in the Drilling and Sampling Protocol Document (GLAL 1984a) were altered slightly to accommodate site conditions. The actual grout slurry mix is compared on a percent weight basis to the specified grout slurry mix below:

Specified Grout Slurry	Actual Grout Slurry
1.2% Bentonite	2-3% Bentonite
6.0% Hydrated Lime (optional)	
59.6% Cement (Portland Type 10)	40-60% Cement (Portland Type 10)
33.2% Water	37-58% Water

The increased amount of bentonite provides a more effective seal in water bearing formations. The bentonite also acts as a 'plasticizing' agent and eliminated the need to add hydrated lime to the grout slurry mix. A cement mix containing slightly less than the amount of cement specified in the protocol was found to be adequate. A small sample of grout slurry was taken from each hole to confirm the setting characteristics of the mix.

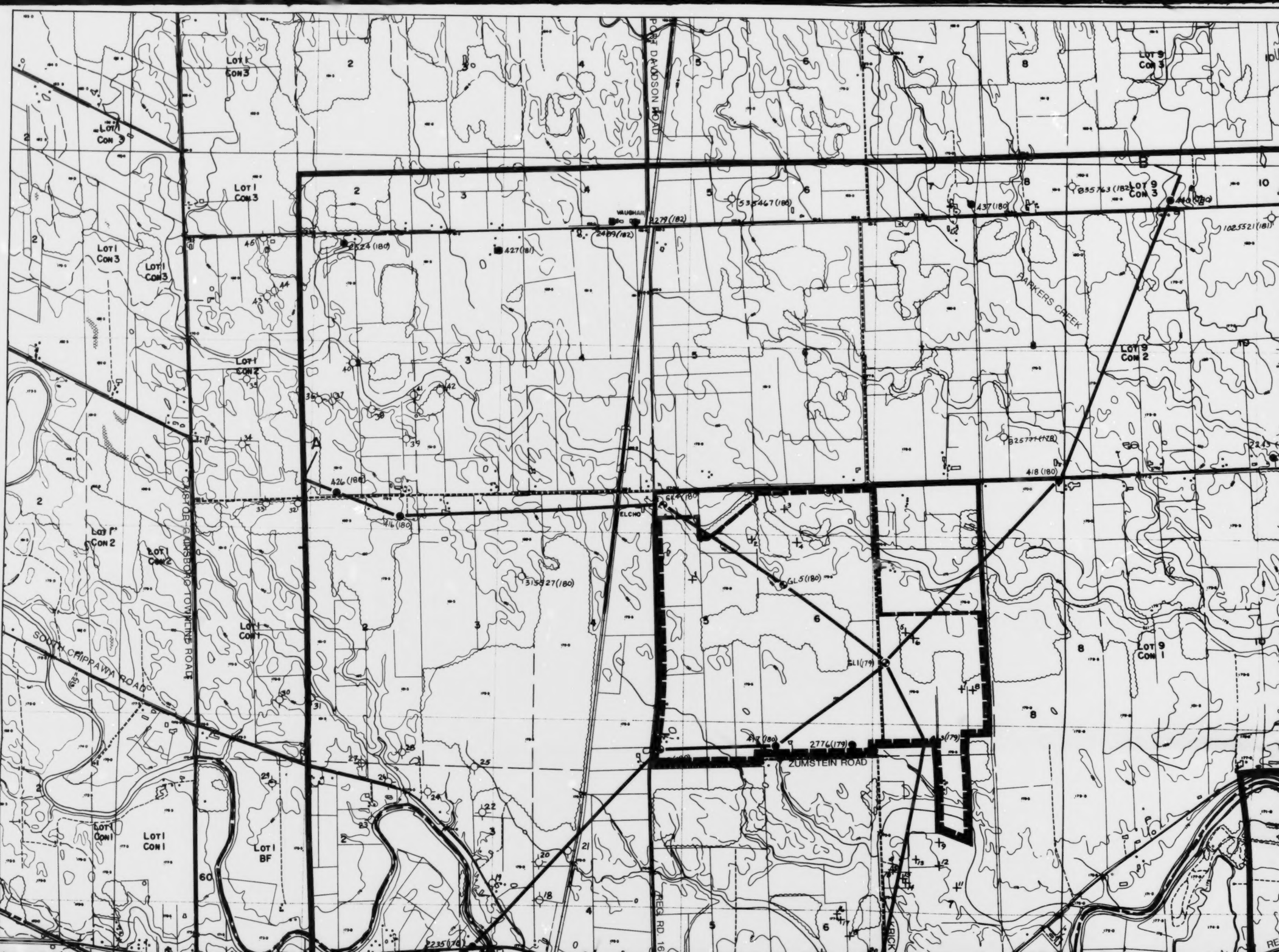
The water used in the grout slurry was obtained locally and was tested wth a Hach Kit for sulphate and chloride content. Details of each grout mix were recorded on the Borehole Plugging Plan/Record for each borehole.

The grout was allowed to set overnight and generally settled to within 1 to 3 m (3-10 ft.) of ground surface. The hole was subsequently backfilled to grade with soil to avoid interference with surface activities such as ploughing or maintenance along road allowances. All

boreholes from this drilling program were successfully grouted.

8.8.4.2 Site cleanup

Efforts were made to restore each drill location to predrilling conditions. The ground was levelled to grade and holes or ruts made by drilling equipment were filled with soil and in some cases resodded. While attempts were made to minimize damage, this was not always possible and compensation was provided in some cases. Photographs were taken of each drill location both before and after the drilling operations and after site cleanup.


LOT 1 CON 3
LOT 1 CON 2
LOT 1 CON 1
LOT 1 BF
LOT 9 CON 3
LOT 9 CON 2
LOT 9 CON 1
PORT DALHOUSIE ROAD
PARKERS CREEK
CASTOR-GANSBORO TOWNLINE ROAD
SOUTH CHIPPAWA ROAD
ZUMSTEIN ROAD
REG RD 16
VAUGHAN
ELCHO
A
B
426 (180)
416 (180)
2524 (180)
427 (181)
2479 (182)
3279 (182)
535467 (180)
437 (180)
355763 (182)
102532 (181)
418 (180)
GL5 (180)
EL1 (179)
2776 (179)
3158927 (180)
2235 (178)

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

GL 5 GARTNER LEE ASSOCIATES LIMITED BOREHOLE

2243 WATER WELL WITH MINISTRY OF ENVIRONMENT NUMBER
(180) ESTIMATED SURFACE ELEVATION IN METRES ABOVE SEA LEVEL

GARTNER LEE ASSOCIATES LIMITED FIELD STATION

OIL AND GAS WELL LOCATION

A A' CROSS-SECTION

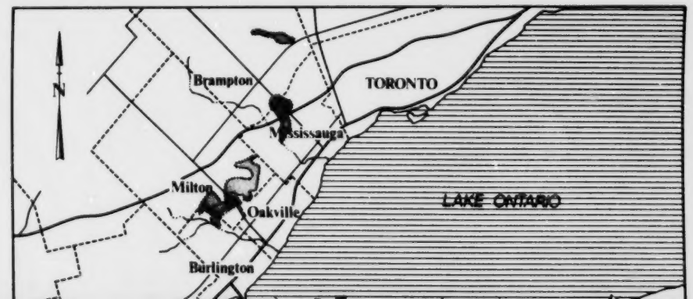
Proposed Acquisition Boundary

Phase 3B Acquisition Boundary

Site Vicinity Study Area Boundary

Key Map: LF-3 Central

Lots 5, 6 and 7; Concession 1; Part of Lot 7; Broken Front Concession; Township of West Lincoln; formerly in the *Township of Gainsborough*



SOUTH CHIPPAWA ROAD
TOWNLINE ROAD
ZUMSTEIN ROAD
LOT 1 CON 1
LOT 1 BF
LOT 9 CON 1
REG. RD. 16
BRICK ROAD
ATTERCLIFFE
PORT DAVIDSON
LOT 6 CON 2
LOT 5 CON 7
LOT 5 CON 2 B
LOT 5 CON 2
LOT 6 CON 2
LOT 50 CON 7
LOT 49 CON 7
LOT 50 CON 6
REG. RD. 15
OSWEGO CREEK
TORONTO HAMILTON & BUFFALO RAILWAY
WELLAND RIVER
SIXTH CON
ATTERCLIFFE STATION
Township of Wainfleet
Town of Dunnville
Contour Interval
1:10000 base mapping
Ministry of Natural Resou

ZUMSTEIN ROAD

CANBOROUGH ROAD

REG. RD. 63

REG. RD 45

CREEK ROAD

REG. RD 16

BEAVER CREEK

LOT 9 CON 1

LOT 50 CON 5

LOT 49 CON 7

LOT 50 CON 6

SIXTH CONCESSION

WELLAND RIVER

FORT DAVIDSON

TORONTO HAMILTON & BUFFALO RAILWAY

Township of Wainfleet

Town of Dunnville

Contour Interval in Metres

1:10 000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

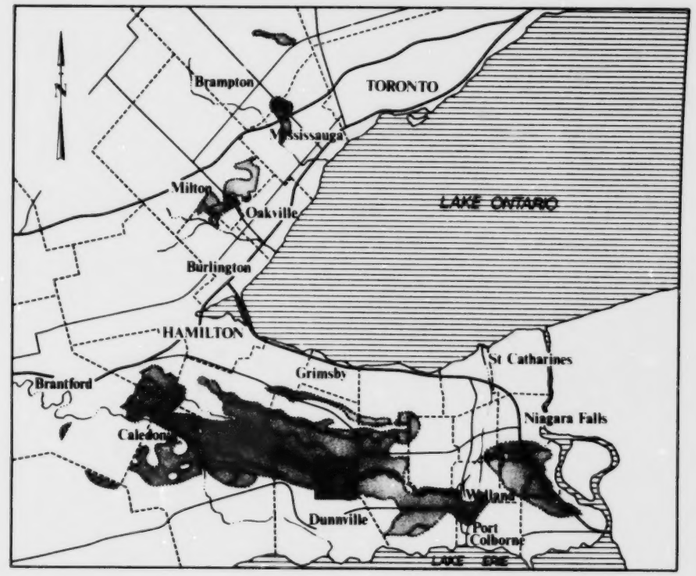
Proposed Acquisition Boundary

Phase 3B Acquisition Boundary

Site Vicinity Study Area Boundary

Key Map: **LF-3 Central**

Lots 5, 6 and 7; Concession I; Part of Lot 7; Broken Front Concession; Township of West Lincoln; formerly in the Township of Gainsborough



1000 feet 0 1000

500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Well and Borehole Locations

September 1985 **FIGURE 4**

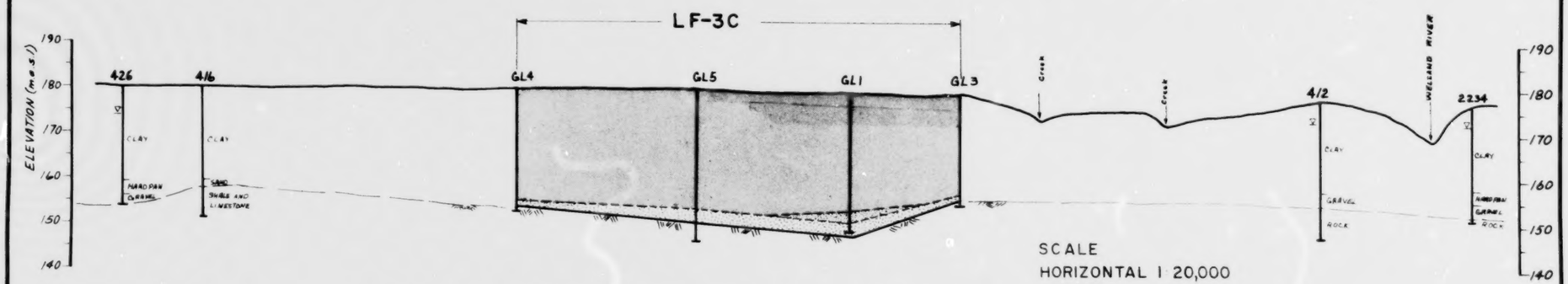
Northwest

Looking Northeast

Southeast

A

A'



(Geologic conditions between boreholes may vary from interpretations shown)

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

Site LF-3C
CROSS-SECTION A-A'
Figure 5

LEGEND

GL 3	Gartner Lee Associates Limited (GLAL) Borehole
417	Ministry of Environment Water Well Record Number
▽	Static Water Level in Well at Time of Well Construction
m a.s.l.	Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- CLAYEY SILT (Upper Glaciolacustrine, Halton Till, Lower Glaciolacustrine)
- SAND (Lower Glaciolacustrine)
- SILT TILL (Lower Till)
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

NOTES:
- Consult Water Well Record Summary and Borehole Logs in Sections B.1 and B.5 for detailed descriptions.
- Elevations are approximate.
- Cross-Section Located in Figure 4.
- To accompany Phase 4A Technical Appendix (Geologic Hydrogeologic and Geotechnical Considerations)

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

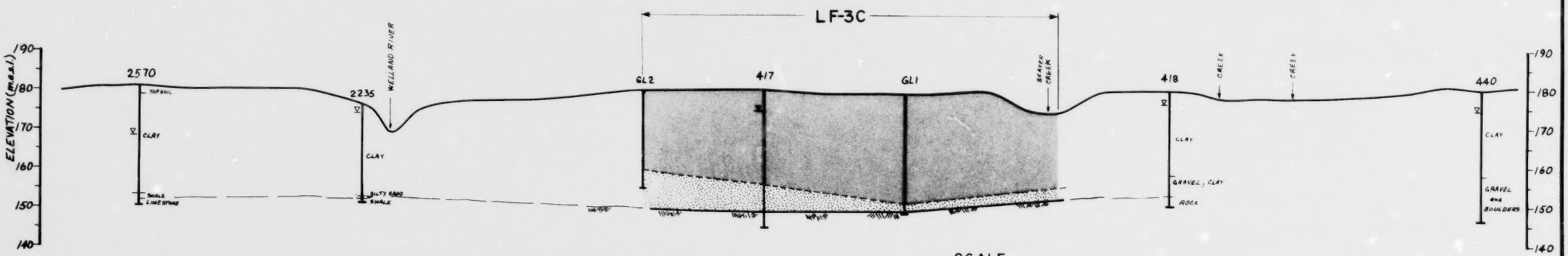
Southwest

Looking Northwest

Northeast

B

B'



(Geologic conditions between boreholes may vary from interpretations shown)

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

Site LF-3C
CROSS-SECTION B-B'
Figure 6

LEGEND

GL 3	Gartner Lee Associates Limited (GLAL) Borehole
417	Ministry of Environment Water Well Record Number
▽	Static Water Level in Well at Time of Well Construction
m a.s.l.	Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- CLAYEY SILT (Upper Glaciolacustrine, Halton Till, Lower Glaciolacustrine)
- SILT TILL (Lower Till)
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

NOTES:
- Consult Water Well Record Summary and Borehole Logs in Sections B.1 and B.5 for detailed descriptions.
- Elevations are approximate.
- Cross-Section Located in Figure 4.
- To accompany Phase 4A Technical Appendix (Geologic Hydrogeologic and Geotechnical Considerations)

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

LOT 1 CON 3

LOT 1 CON 3

LOT 1 CON 3

LOT 1 CON 3

LOT 1 CON 3

LOT 1 CON 2

LOT 1 CON 2

LOT 1 CON 1

LOT 1 CON 1

LOT 1 BF

LOT 9 CON 3

LOT 9 CON 3

LOT 3 CON 2

LOT 9 CON 1

POPE DAWSON ROAD

SOUTH CHIPPAWA ROAD

CASTLE CAMBORO TOWNLINE ROAD

ZUMSTEIN ROAD

REG. RD. 16

ELCHO

VAUGHAN

FRANKERS CREEK

KRICK

60

427
21.9

426
24.2

446
21.3

437
30.5

441
24.3

445
31.4

441
24.84

441
31

2489
20.4

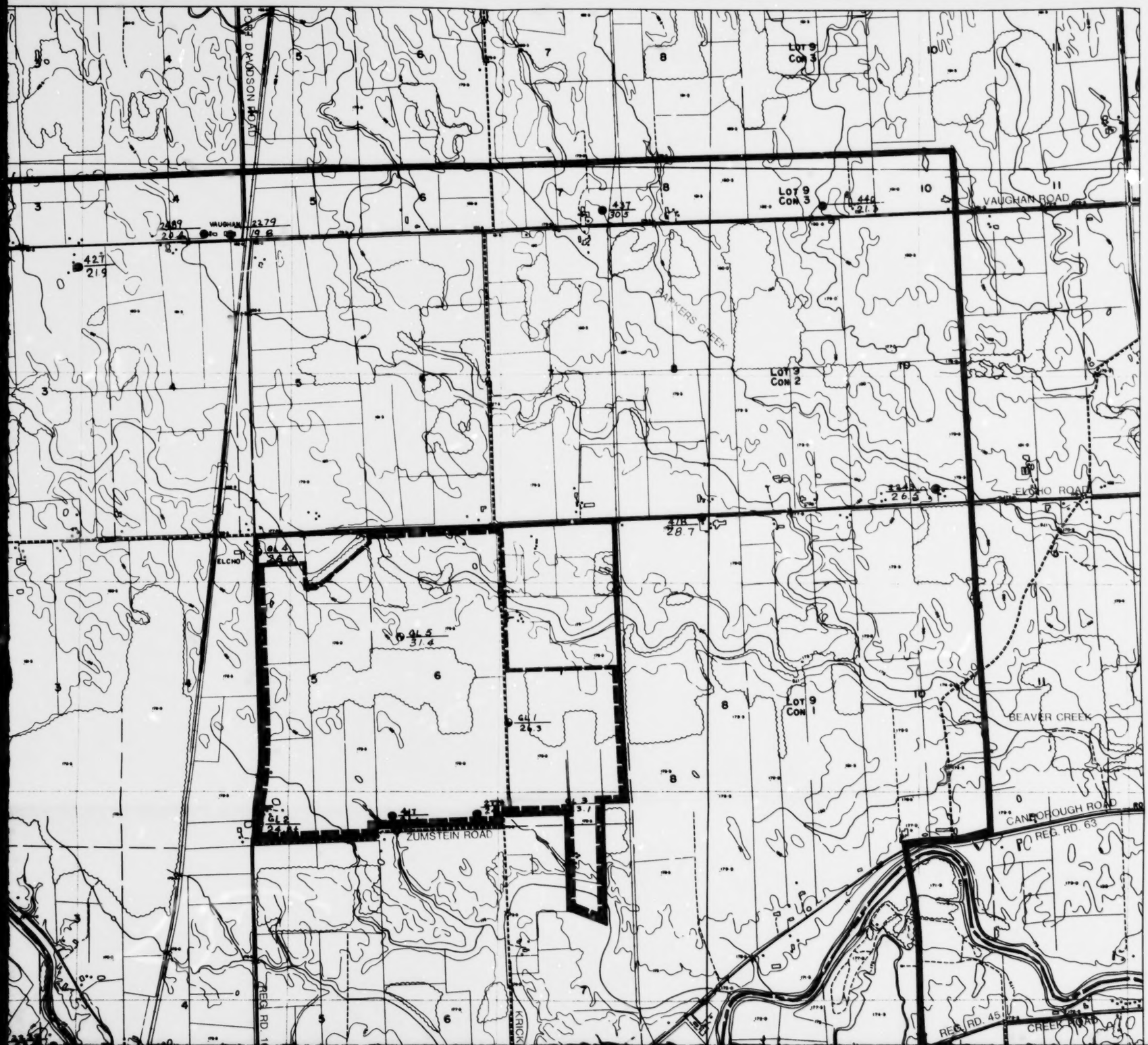
2379
19.8

4374
26.2

4416
20.7

4418
28.7

2348
26.5



OWMC **Ontario Waste Management Corporation**

Consultant: Gartner Lee Associates Limited

Legend:

GL 5 GARTNER LEE ASSOCIATES LIMITED BOREHOLE

2776 WATER WELL WITH MINISTRY OF ENVIRONMENT NUMBER

29.1 THICKNESS OF CONFINING LAYER IN METRES

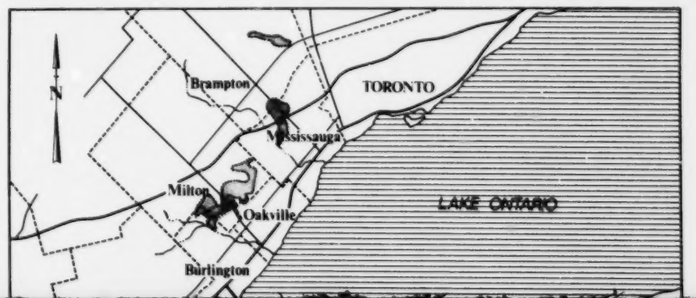
Proposed Acquisition Boundary

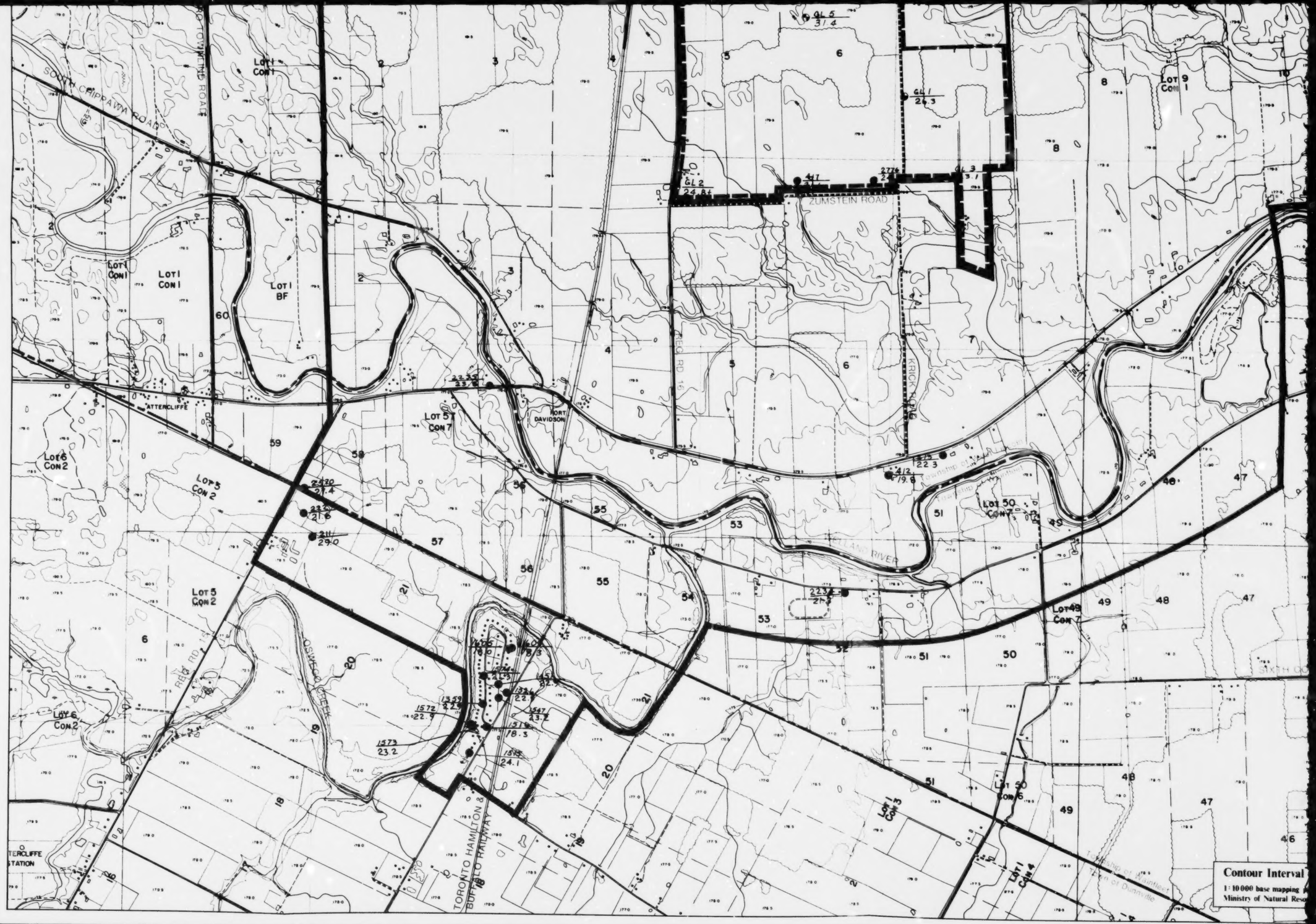
Phase 3B Acquisition Boundary

Site Vicinity Study Area Boundary

Key Map: **LF-3 Central**

Lots 5, 6 and 7; Concession 1; Part of Lot 7; Broken Front Concession; Township of West Lincoln; formerly in the Township of Gainsborough

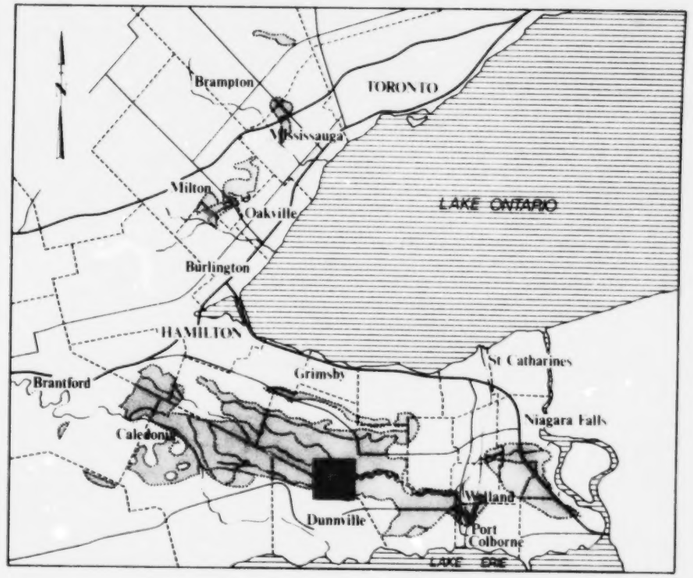



SOUTH CAYUGA ROAD
SOUTH TOWNLINE ROAD
LOT 1 CON 1
LOT 1 CON 1
LOT 1 BF
ZUMSTEIN ROAD
REID RD 1
KRICK ROAD
ATTERCLIFFE
PORT DAVIDSON
LOT 5 CON 7
LOT 6 CON 2
LOT 5 CON 2
LOT 5 CON 2
OSWEGO CREEK
LOT 6 CON 2
TORONTO HAMILTON & BUFFALO RAILWAY
ATTERCLIFFE STATION
LOT 9 CON 1
LOT 50 CON 7
LOT 49 CON 7
LOT 50 CON 6
LOT 1 CON 4
GL 5 31.4
GL 1 24.3
GL 2 24.8
GL 3 31.1
Contour Interval
1:10 000 base mapping
Ministry of Natural Resc

Proposed Acquisition Boundary
Phase 3B Acquisition Boundary
Site Vicinity Study Area Boundary

Key Map: **LF-3 Central**

Lots 5, 6 and 7; Concession I; Part of Lot 7; Broken Front Concession; Township of West Lincoln; formerly in the Township of Gainsborough



1000 feet 0 1000
500 metres 0 500

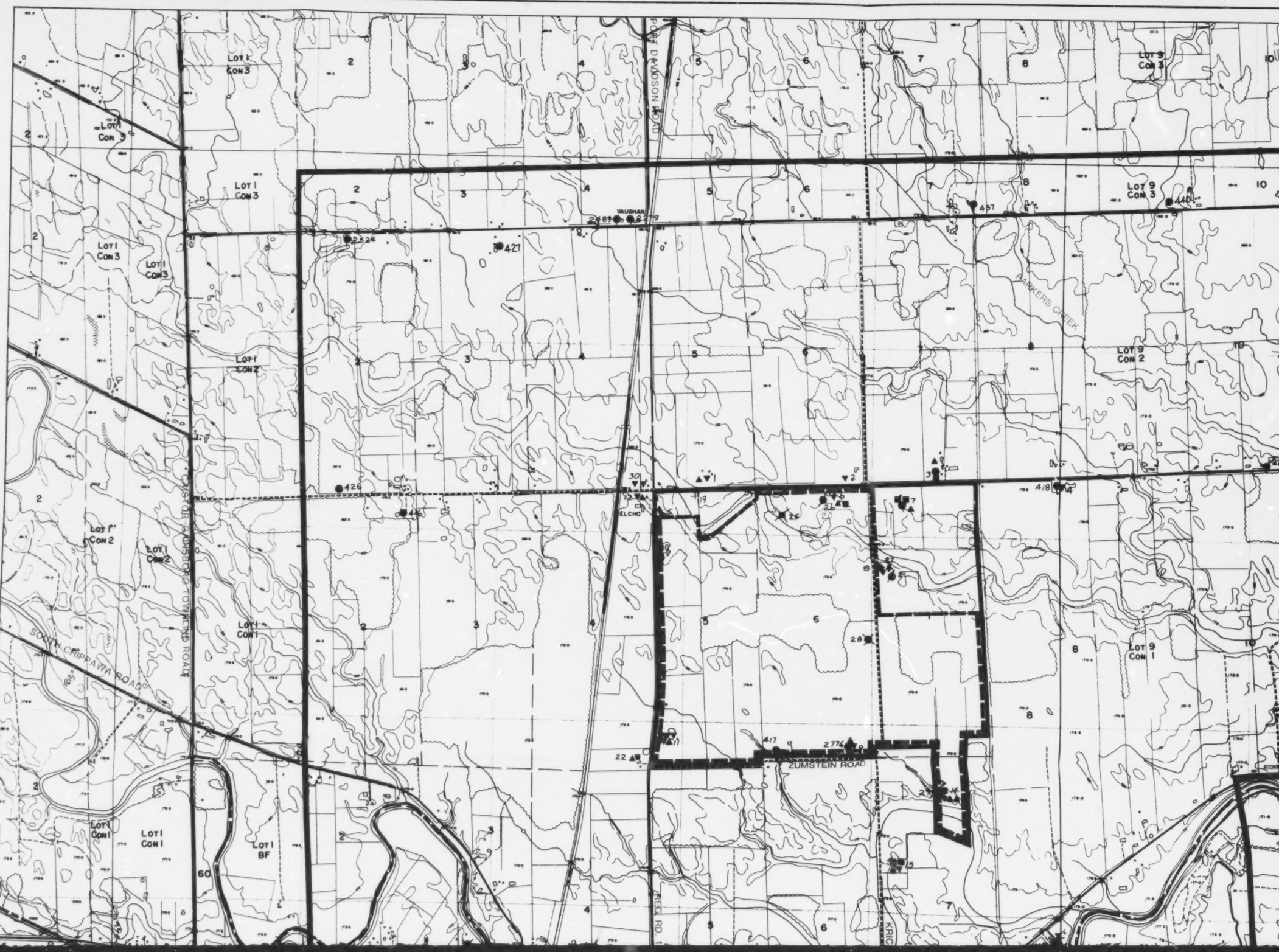
GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

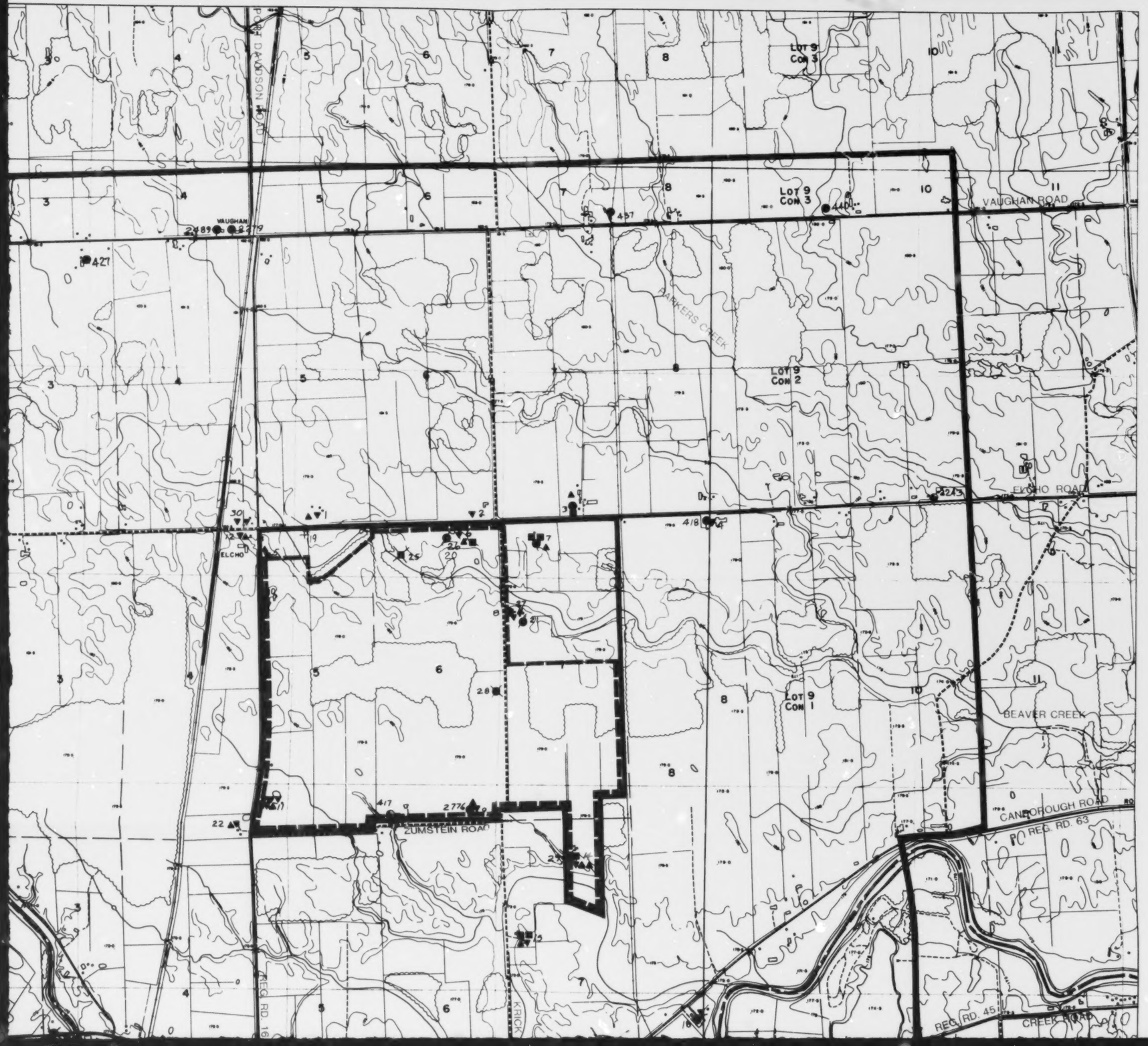
Confining Layer Thickness

September 1985 **FIGURE 7**

Contour Interval in Metres

1:10000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984


LOT 1 CON 3
LOT 1 CON 2
LOT 9 CON 3
LOT 9 CON 2
LOT 9 CON 1
PORT DAVIDSON ROAD
CASTOR SUMSBORO TOWNLINE ROAD
SOUTH CHIPPAWA ROAD
ZUMSTEIN ROAD
PARKERS CREEK
ELCHO
VAUGHAN
REG. RD. 1
KRIC



OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

- ● , ● DRILLED WELL COMPLETED IN OVERBURDEN, BEDROCK
- ■ DUG OR BORED WELL
- FLOWING CONDITIONS
- / , X UNUSED, ABANDONED WELL
- ▲ DUGOUT OR POND
- ▼ CISTERN
- \+ ADDITIONAL FIELD INFORMATION

NOTE: Details for wells with Ministry of Environment numbers (3 and 4 digits) are provided in the Summary of Water Well Data (Table 4, Section 8.1); Other numbers accompany wells, cisterns, dugouts or ponds, and locations where additional field information was gathered. Details for these are provided in the Summary of Site Interview Data (Table 6, Section 8.3)

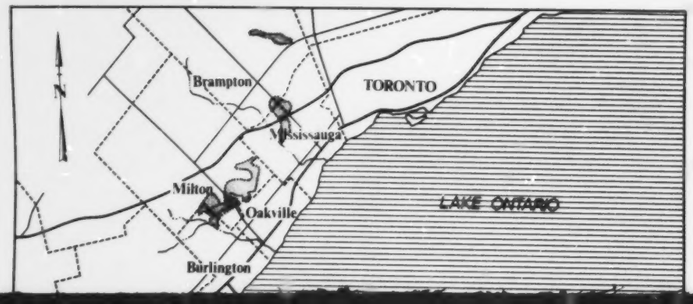
Proposed Acquisition Boundary

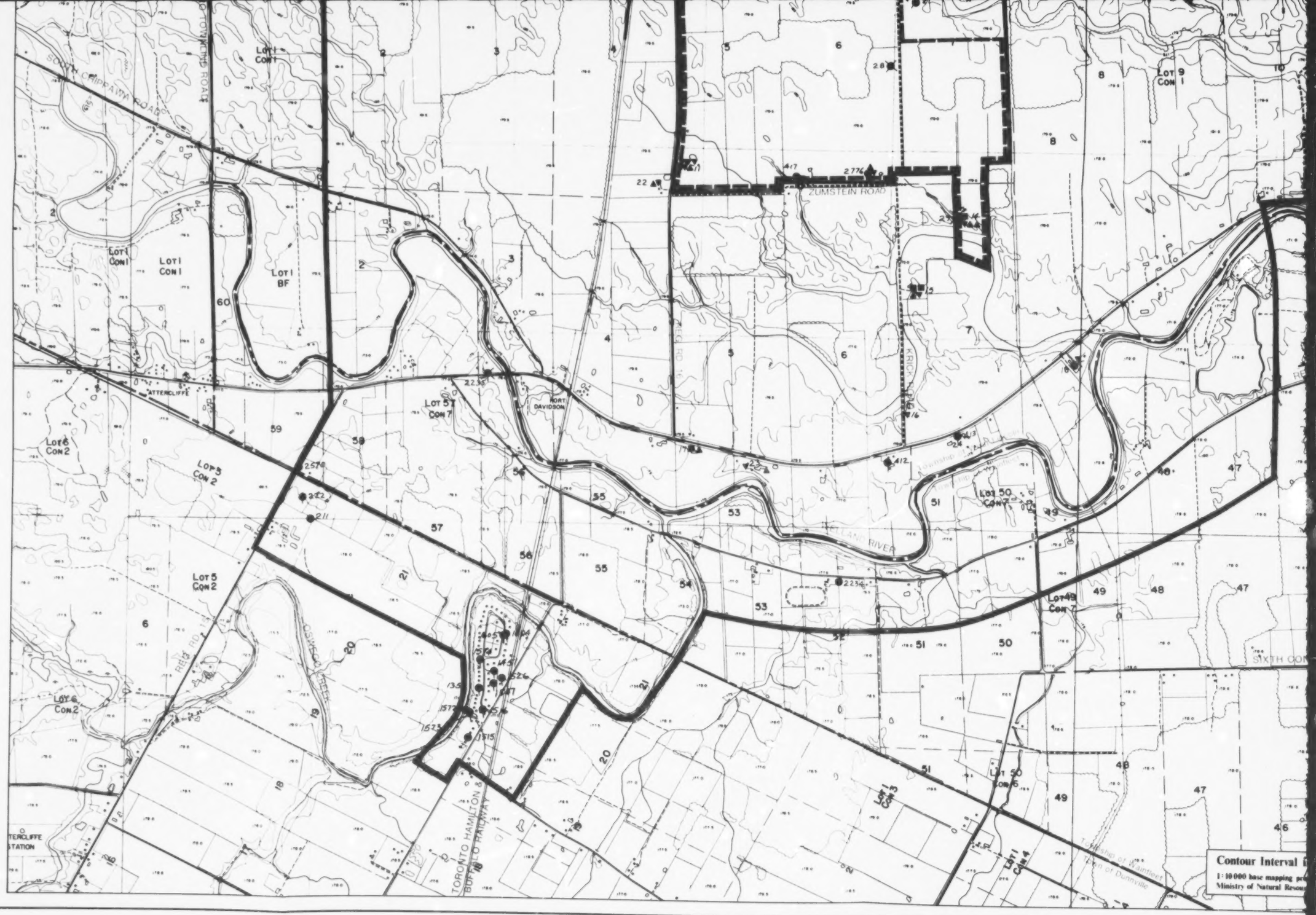
Phase 3B Acquisition Boundary

Site Vicinity Study Area Boundary

Key Map: **LF-3 Central**

Lots 5, 6 and 7; Concession 1; Part of Lot 7; Broken Front Concession; Township of West Lincoln; formerly in the Township of Gainsborough




SOUTH CAYUGA ROAD
TOWNLINE ROAD
LOT 1 CON 1
LOT 1 CON 1
LOT 1 CON 1
LOT 1 BF
ZUMSTEIN ROAD
LOT 9 CON 1
ATTERCLIFFE
FORT DAVIDSON
LOT 51 CON 7
LOT 6 CON 2
LOT 5 CON 2
LOT 50 CON 7
LOT 49 CON 7
LOT 6 CON 2
LOT 5 CON 2
LOT 50 CON 6
LOT 1 CON 4
REED RD
OSWEGO CREEK
TORONTO HAMILTON & BUFFALO RAILWAY
GRAND RIVER
KRICKS CREEK
SIXTH CON
ATTERCLIFFE STATION
Township of Rainham
Town of Dunnville
Contour Interval
1:10 000 base mapping
Ministry of Natural Resou

wells, cisterns, dugouts or ponds, and locations where additional field information was gathered. Details for these are provided in the Summary of Site Interview Data (Table 6, Section 8.3)

Proposed Acquisition Boundary

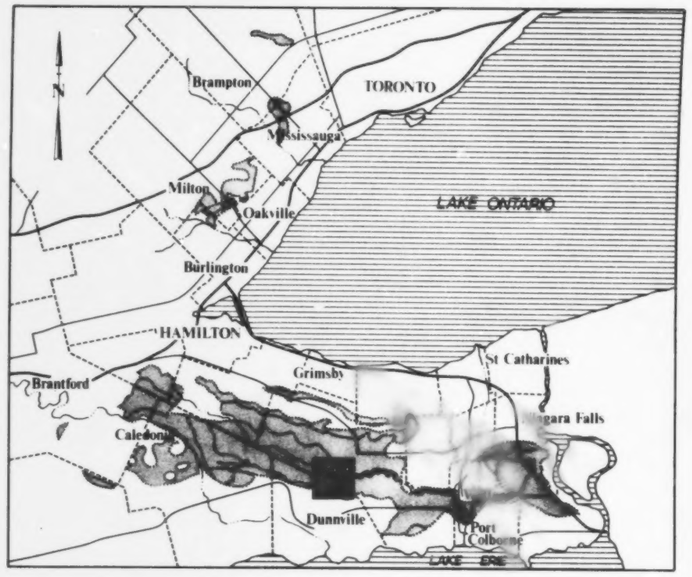
Phase 3B Acquisition Boundary

Site Vicinity Study Area Boundary

Key Map:

LF-3 Central

Lots 5, 6 and 7; Concession I; Part of Lot 7; Broken Front Concession; Township of West Lincoln; formerly in the Township of Gainsborough



1000 feet 0 1000

500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Ground Water Use

September 1985

FIGURE 8

Contour Interval in Metres

1:10000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

Number/
Numéro

2

SITE SELECTION PROCESS - PHASE 4A

TECHNICAL APPENDIX LF-9C

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS

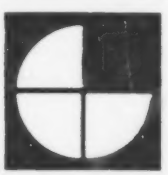
A REPORT PREPARED FOR
ONTARIO WASTE MANAGEMENT CORPORATION
BY
GARTNER LEE ASSOCIATES LIMITED

THIS REPORT IS ONE OF EIGHT TECHNICAL APPENDICES DESCRIBING GEOLOGIC, HYDROGEOLOGIC AND GEOTECHNICAL CONSIDERATIONS OF THE CANDIDATE SITES. IT SUPPORTS THE COMPARATIVE EVALUATION STUDY WHICH IS ENTITLED "SITE SELECTION PROCESS; PHASE 4A, SELECTION OF PREFERRED SITE(S), GEOLOGIC, HYDROGEOLOGIC AND GEOTECHNICAL CONSIDERATIONS".

SEPTEMBER, 1985.

PROJECT 85-S18.3

Gartner Lee
Associates Limited



Gartner Lee Associates Limited

Consulting Engineering
Geologists
Biologists and
Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-477-8400
Telex-06-986278

September 6, 1985.

Dr. B.D. Mitchell,
Director of Corporate Planning
and Development,
Ontario Waste Management Corporation,
11th Floor,
2 Bloor Street West,
Toronto, Ontario,
M4W 3E2.

Attention: Mr. J.G. Micak,
Manager,
Environmental Projects

Dear Dr. Mitchell:

Re: Site Selection Process - Phase 4A
Technical Appendix LF-9C - Geologic, Hydrogeologic,
and Geotechnical Considerations

Enclosed is our final report on the Geologic, Hydrogeologic, and Geotechnical Considerations at Candidate Site LF-9C. Similar reports prepared for each of the other candidate sites will form the basis for site comparisons.

Thank you for allowing our company to be of service. If clarifications are required please contact our office.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

Grant Anderson

E.G. Anderson, P.Eng.,
Project Director.

KJG:jcm
Enclosures.

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6.	CROSS-SECTION B-B'	in map pocket
7.	CONFINING LAYER THICKNESS	in map pocket
8.	GROUND WATER USE	in map pocket
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6. SUMMARY OF SITE INTERVIEW DATA 53

STUDY TEAM

This report was prepared under the overall direction of Grant Anderson, P.Eng., Project Director and Gunther Funk, Project Manager.

Major contributing authors were:

Hydrogeology	-	Kenneth Goff
Geology	-	Andrew Cooper
Geotechnics	-	Douglas Jagger, P.Eng.
Field Co-ordination	-	Norbert Woerns

1.0 INTRODUCTION

1.1. BACKGROUND

The Ontario Waste Management Corporation's (OWMC) site selection process to locate facilities to treat hazardous wastes and to dispose the treated waste residues has been a phased process which began in 1981. Initial studies (Gartner Lee Associates Limited 1984c) identified 261 hydrogeologic areas throughout southern Ontario which were grouped into six zones. Within the Golden Horseshoe, zone 1 and 2 lands were considered most favourable for facility siting. Twenty candidate areas were identified within the Zone 1 and 2 lands in the Golden Horseshoe in 1983. A total of 152 sites were identified in these twenty candidate areas in 1984 and this number was subsequently reduced in stages to sixteen potential sites and finally to eight candidate sites through the application of various constraints, screening processes, and ranking systems based on multidisciplinary factors. A more complete discussion of the site selection process is provided in the report entitled "Site Selection Process; Phase 4A, Selection of Preferred Site(s); Geologic, Hydrogeologic and Geotechnical Considerations" (GLAL 1985).

The present stage of study is the comparative assessment of the eight candidate sites. This Gartner Lee Associates Limited (GLAL) report documents and interprets available geologic, hydrogeologic, and geotechnical information for Site LF-9C and serves as the data base for input to the site comparison study. The candidacy of this site is based on the potential development of a landfill and a physical-chemical treatment plant and incinerator. The

Phase 3B preliminary assessment of this site was based primarily on existing data (GLAL 1984b). Phase 4A investigations described in this report add significantly to the geologic, hydrogeologic, and geotechnical data base.

1.2 OBJECTIVES AND SCOPE

The objectives of this report are to provide data for Site LF-9C as input to the interdisciplinary comparisons of siting options and ranking. These objectives have been met through additional investigations at each site. The existing data base has been upgraded where possible and five boreholes have been drilled on the site. Each of the boreholes has been continuously sampled to provide detailed geologic logs and soil samples. Boreholes were not instrumented and were grouted on completion.

1.3 LOCATION

Site LF-9C is located in the central portion of the Niagara Peninsula roughly midway between Hamilton and Fort Erie. It is shown together with the other candidate sites in Figure 1 and is presented in greater detail in the figures in the map pockets at the rear of the report.

The site under consideration in this Technical Appendix covers approximately 135 hectares (ha) and includes Lot 18 and part of Lot 17, Concession 3, West Lincoln Township, Regional Municipality of Niagara. It is bounded on the east by Schram Road, on the north by Highway 20, and on the south by Vaughan Road. The site is approximately 20 km southwest of St. Catharines and 35 km southeast of Hamilton. It is

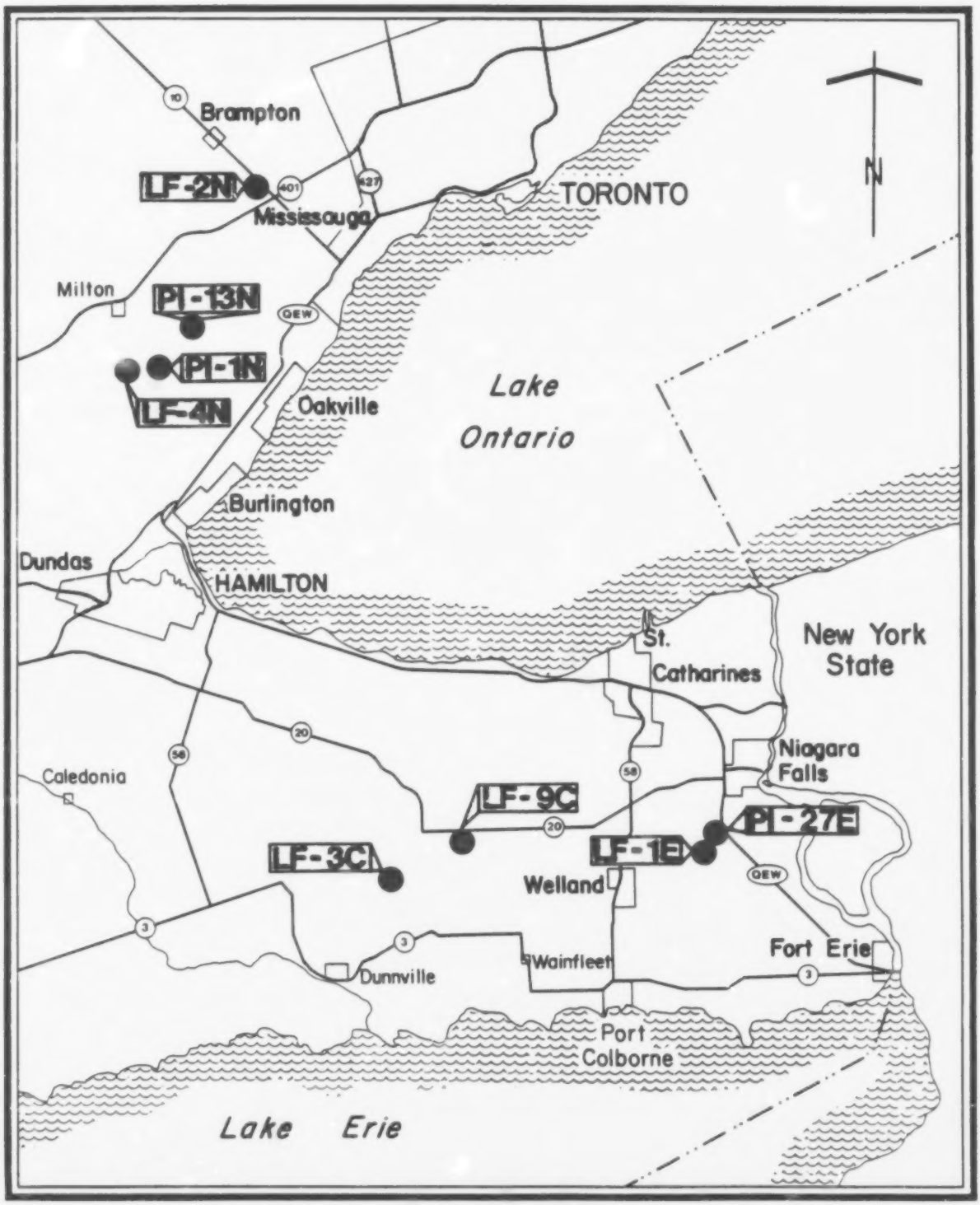


FIGURE 1 LOCATION OF CANDIDATE SITES

about 3 km northeast of Wellandport, 6 km east of Bismarck, and 2 km northwest of the Welland River at its closest point. The site is roughly centered in a study area of about 2000 ha.

2.0 METHODOLOGY

The methodology employed in the collection, compilation and interpretation of the information base presented in this technical appendix report is described below and illustrated in Figure 2.

2.1 DATA COLLECTION

The following sources of information were used:

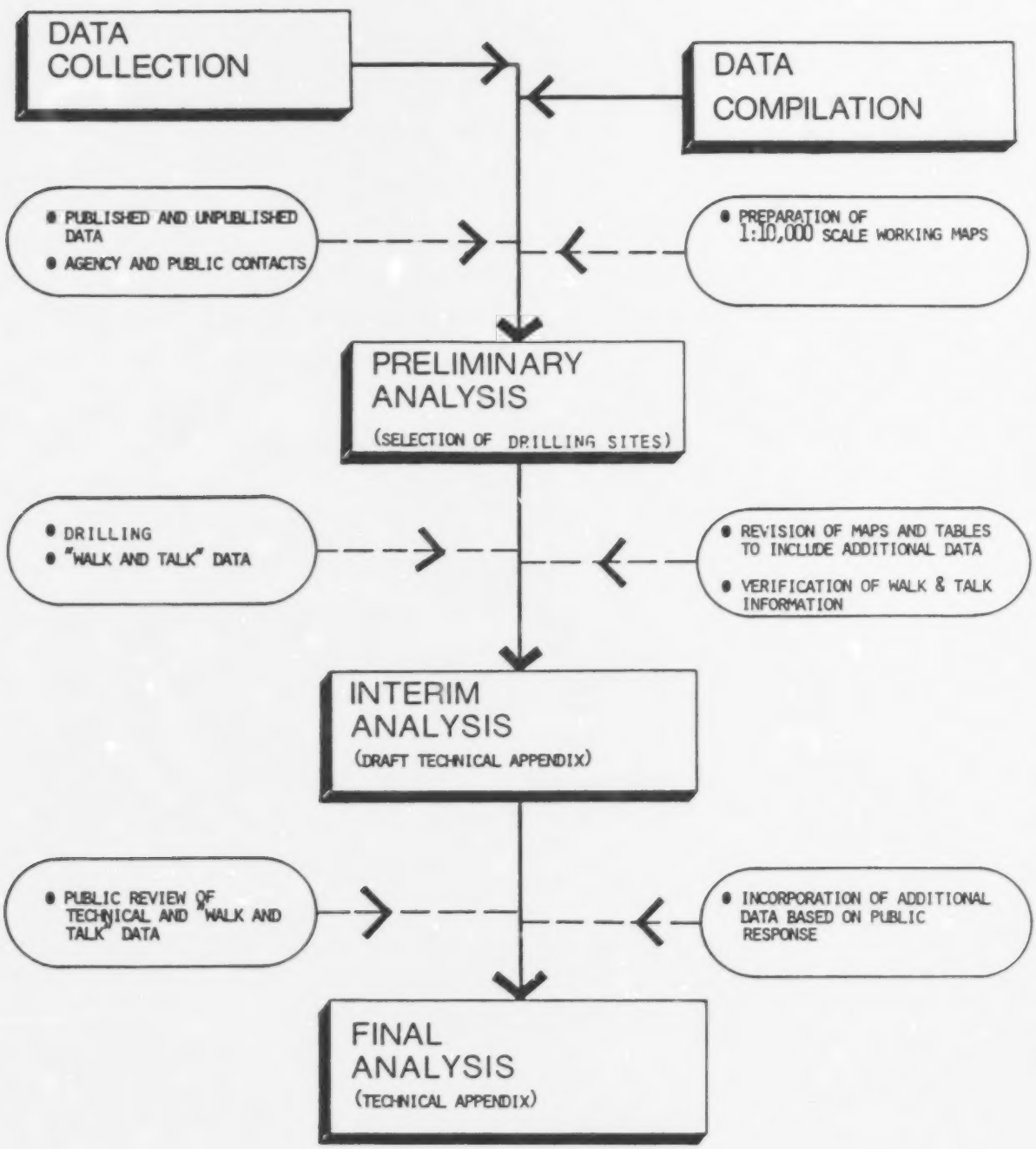
- water well records, published and unpublished reports, maps and "open file" reports,
- interviews with government agency personnel and local residents; and
- onsite drilling and field survey results.

2.1.1 DATA BASE

Numerous reports and maps which contain both regional and local information on the geology and hydrogeology of the candidate sites were assembled during the earlier phases of the site selection process. Reports specific to this site are referenced in the text and are listed in Section 7.0.

Figure 2

Methodology Flow Chart


DATA COLLECTION
DATA COMPILATION
• PUBLISHED AND UNPUBLISHED DATA
• AGENCY AND PUBLIC CONTACTS
• PREPARATION OF 1:10,000 SCALE WORKING MAPS
PRELIMINARY ANALYSIS
(SELECTION OF DRILLING SITES)
• DRILLING
• "WALK AND TALK" DATA
• REVISION OF MAPS AND TABLES TO INCLUDE ADDITIONAL DATA
• VERIFICATION OF WALK & TALK INFORMATION
INTERIM ANALYSIS
(DRAFT TECHNICAL APPENDIX)
• PUBLIC REVIEW OF TECHNICAL AND "WALK AND TALK" DATA
• INCORPORATION OF ADDITIONAL DATA BASED ON PUBLIC RESPONSE
FINAL ANALYSIS
(TECHNICAL APPENDIX)

Supplementary information was collected with the co-operation of government and other agencies. This information includes:

- copies of original water well records from the Ministry of the Environment, and

- copies of oil and gas well records from the Ministry of Natural Resources.

These data are presented in Section 8.0. Copies of the data are on file.

2.1.2 INTERVIEWS

Additional information regarding site geology and water use was obtained during interviews with government agency personnel and local residents. The results of the interviews are presented in the summaries prepared for agency meetings (by GLAL) and on resident interview forms (prepared by Ecologistics Limited). Meetings were held with the local public interest group made up of residents and other interested individuals who identified items of geologic and hydrogeologic interest. The summaries of meetings and the interview forms are on file. Local water use information summarized from the interview forms is tabulated in Table 6 (Section 8.3).

2.1.3 DRILLING AND FIELD SURVEY RESULTS

Borehole locations were selected based on preliminary analysis of available data and input from the public. Five boreholes were completed at selected locations on the site to investigate the expected character and continuity of the

geologic materials. Drilling and sampling procedures are presented in the document entitled "Phase 4A Drilling and Sampling Activities and Protocol" (GLAL 1984a) and the detailed field methods employed during this study are summarized in Section 8.8.

The drilling program involved the collection of continuous samples from boreholes. These samples were photographed and described in the field, placed in suitable containers, and shipped to the Ontario Geological Survey in Toronto for storage. Splitspoon samples were taken at 1.5 m intervals to obtain standard penetration resistance values and samples for moisture content determinations in order to carry out preliminary geotechnical assessments. Detailed borehole logs were prepared based on the field descriptions and on subsequent re-examination of the samples in storage. These logs are presented as part of the supporting information in Section 8.5.

Hand-auger holes were also dug at the request of local residents to answer questions or concerns regarding shallow geologic conditions. Each location investigated has been classed as a 'field station' and the locations and descriptions of each are provided in Section 8.4.

2.2. DATA COMPILATION AND ANALYSIS

Data compilation and analysis have proceeded in a staged fashion which is depicted in Figure 2. In the initial work, information such as water well records was compiled in summary tables and illustrated on a series of working maps and cross sections at a scale of 1:10 000. Maps included plots of:

- data point locations (all sources);
- geology (Ontario Geological Survey reports), constraint mapping results from Phase 3B, and Ministry of the Environment maps and reports);
- bedrock elevations (water well and oil and gas well data);
- confining layer thickness (water well data);
- aquifer thickness (water well data);
- anomalies such as granular zones (water well data).

These maps were used to establish the geographic distribution of existing data points and to expand (at a more detailed scale) the preliminary interpretation of geologic and hydrogeologic conditions presented in the Phase 3B reporting (GLAL 1984b). Tentative drilling locations were then identified based on these preliminary analyses.

Following the selection of tentative drilling locations, GLAL personnel met with interested parties to present the results of the preliminary analysis and to discuss the purpose and scope of the Phase 4A program. Additional information on local geologic and hydrogeologic conditions was collected during these meetings. Landowners and tenants were contacted at this time to obtain permission to drill on their properties, and drill site locations were modified based on local inputs.

A separate data collection program commonly referred to as the "Walk and Talk" survey was undertaken. During this survey, individual residents were interviewed by personnel from Ecologistics Limited and the results were recorded in a questionnaire format. Among the multidisciplinary questions were several which were provided by

Gartner Lee Associates Limited and which related specifically to water supply and use. The collection of ground water information and related water use data was limited primarily to the site and to adjacent properties.

With the completion of the drilling and public survey programs, the working maps were revised to incorporate the additional information that was collected. This technical appendix presents the interpretation of geologic, hydrogeologic, and geotechnical conditions at Site LF-9C to date. Draft copies of the data summaries were circulated to the local interest groups as a check for completeness and accuracy.

3.0 REGIONAL GEOLOGY AND HYDROGEOLOGY

The geology and hydrogeology of the Niagara Peninsula are summarized and discussed in reports prepared for the Ontario Waste Management Corporation (GLAL 1984b,c). This section is based on these reports and the reader is referred to them for more detail and for a complete list of references on which they are based.

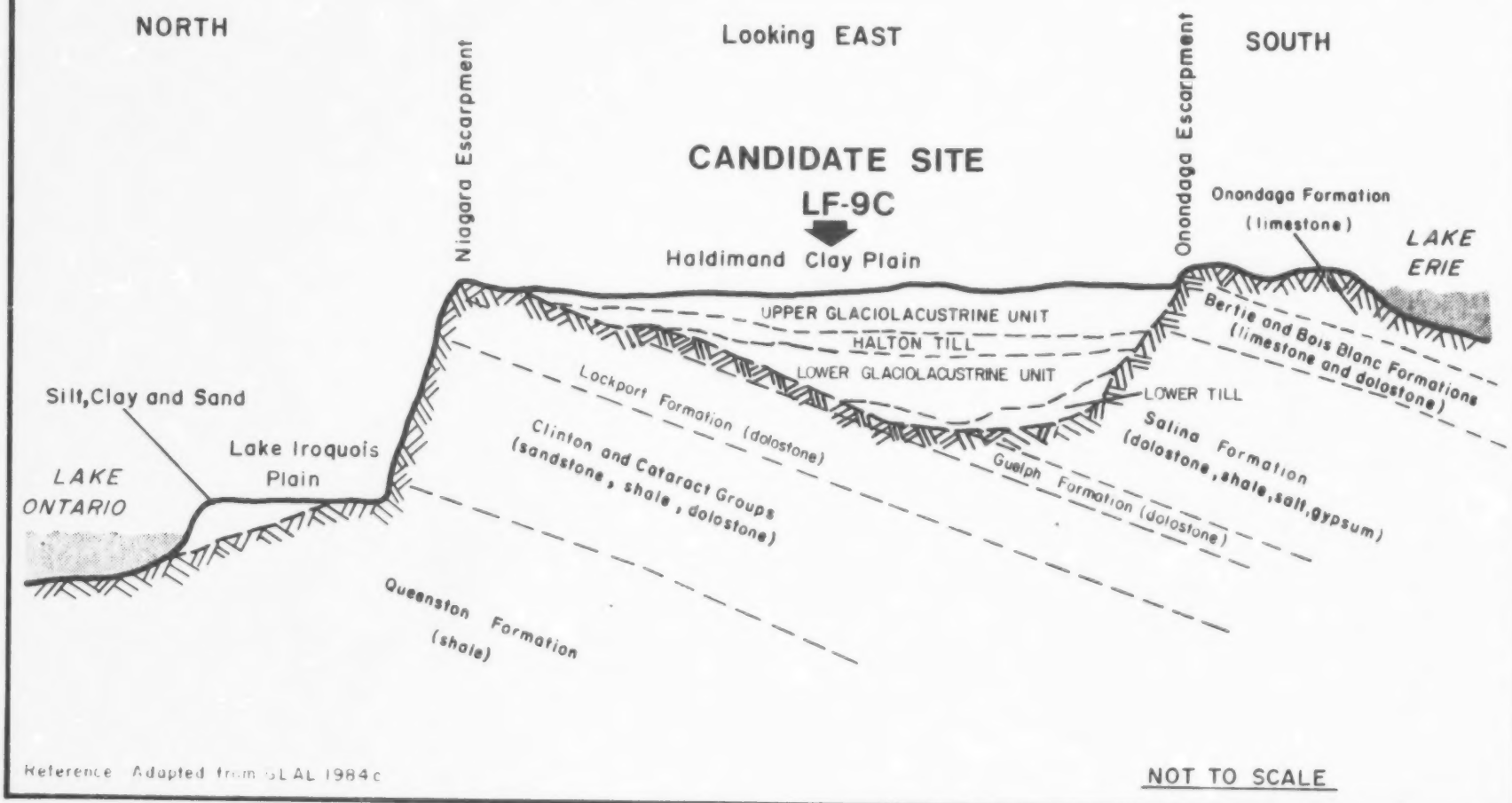
3.1 REGIONAL GEOLOGY

3.1.1 BEDROCK GEOLOGY AND OVERBURDEN THICKNESS

Bedrock in the Niagara Peninsula consists of a sequence of sedimentary formations which dip slightly toward the south. The southerly dip exposes the various formations on the

FIGURE 3

Cross–Section Sketch Through The Eastern Niagara Peninsula



Reference: Adapted from GLAL 1984c

NOT TO SCALE

Gartner Lee Associates Limited

buried bedrock surface in east-west trending bands. Figure 3 shows the approximate location of Site LF-9C on a generalized cross-section of the Peninsula and names the major bedrock units. The site is located over a bedrock depression of regional dimensions between the Niagara and Onondaga escarpments slightly north of the contact of the Guelph and Salina formations. Depths to bedrock in the vicinity of the site are generally in the 30 to 35 m range.

3.1.2 QUATERNARY GEOLOGIC HISTORY

Regional overburden units from oldest to youngest are (1) a lower till directly over the bedrock (2) a lower glaciolacustrine unit, (3) an upper till (Halton Till), and (4) an upper glaciolacustrine unit (Figure 3). The geologic sequence of events associated with the deposition of these units began with a major ice advance over the Niagara Peninsula which laid down the lower till. This advance occurred approximately 23 000 years ago and the ice remained there until it withdrew northward approximately 14 000 years ago. Deposition of the lower glaciolacustrine unit occurred in a subsequent glacial lake and was interrupted by a readvance of the ice which deposited the Halton Till about 13 000 to 12 000 years ago. As the Halton ice withdrew, a lake re-formed in front of it and the upper glaciolacustrine unit was deposited. Following drainage of this lake, the upper glaciolacustrine unit has been subjected to weathering and erosion to produce the present landscape.

3.1.3 QUATERNARY GEOLOGY

Generalized descriptions of each of the major overburden units are presented to provide a regional perspective on

their characteristics and distribution. These are also used to place the discussion of the site geology into its proper context.

A sandy silt to silty sand till occurs above the bedrock at scattered locations throughout the Niagara Peninsula (Feenstra 1974, 1975, 1981, Barnett 1975) and it is generally acknowledged to be the Wentworth Till. This unit is also referred to in the literature as the "lower till" and this term is used here. The lower till is encountered in all five onsite boreholes and is inferred in approximately half the water well logs in the vicinity where it is identified as 'clay and stones', 'clay and gravel', and 'hardpan'. A few water well records report sand and gravel occurrences above and below the lower till deposit, however there is limited information to detail their relationships to adjacent units. Since none of the GLAL boreholes on this site or on other sites in the Peninsula detected basal granular deposits, it is considered that the sands and gravels which are reported in the water well records are discontinuous.

Owen (1969, 1972) and Feenstra (1981) have described a buried lower glaciolacustrine deposit between the lower till and the Halton Till. They note a regional composition which includes clay, silt, and sand and indicate that this layered deposit is often only a few metres thick. The lower glaciolacustrine unit occurs between the two tills in the GLAL boreholes and tends to be silty to clayey in texture.

The Halton Till occurs between the upper and lower glaciolacustrine units over most of the Niagara Peninsula. It is generally buried beneath the upper glaciolacustrine

deposits and may occasionally be observed at surface where the upper glaciolacustrine deposit has been eroded in valleys, where the Halton Till thickens in moraines, or where the bedrock outcrops at escarpments. Till composition in the central portion of the Peninsula reflects the silts and clays of the underlying glaciolacustrine deposits which are incorporated into it. Feenstra (1981) notes that the typically clayey and silty Halton Till deposits are interspersed with sand and silty sand lenses on several moraines in the Niagara area. Portions of the Halton Till may be waterlain according to Feenstra (1981).

The upper glaciolacustrine unit consists essentially of silt and clay. This unit occurs at surface over a large portion of the Niagara Peninsula and underlies the Haldimand Clay Plain Feenstra (1981) describes it as a "massive or stratified (varved in places) silty clay with generally more than 50% clay and 5% sand". Feenstra (1975) also notes that this unit has been observed to be up to 16 m thick. Thin lenses of sand have been observed within the upper 2 m of the upper glaciolacustrine unit at several locations in the region. Glaciolacustrine deposits occur at surface over the study area and most of the area in the vicinity. The upper and lower glaciolacustrine units and the Halton Till are considered to comprise the 'clay' deposits which account for most of the overburden materials described in the water well logs (Section 8.1).

Alluvial deposits occur in association with flood plains of the streams and rivers in the region and are confined laterally and from below by the upper glaciolacustrine unit. They tend to be generally fine-textured reflecting available source material and low to moderate stream gradients.

3.2 REGIONAL HYDROGEOLOGY

The regional distribution of hydrostratigraphic units is illustrated in Figure 3. The Salina and the Guelph formations are major regional aquifers and their contact lies near the site. The Guelph aquifer produces the better yields and the better water quality in the area although the water may locally be mineralized. Water quality in the Salina aquifer is commonly 'sulphurous' due to the presence of evaporites (primarily gypsum) in the carbonate sequence. Permeability in both aquifers is usually best-developed in the upper few metres of bedrock as a result of fracturing and solution enhancement.

Basal sand and gravel deposits which directly overlie the bedrock are reported in numerous water well records and their regional distribution is described in previous reports (GLAL 1984b,c). These basal granular deposits are occasional sources of water supply to drilled wells, however it is not unusual for drillers to develop wells in the bedrock after noting sand and/or gravel above the rock. Where granular deposits overlie the rock it is reasoned that they are in good hydraulic connection with the bedrock. The till is sandy and silty in texture with frequent pebbles and cobbles. It is not generally a source of water.

The upper and lower glaciolacustrine units and the Halton and lower tills comprise a single hydrostratigraphic unit of regional extent which is characterized by low hydraulic conductivities and which is referred to in this report as the confining layer. Downward hydraulic gradients exist across this unit, however ground water flow rates and

quantities are very small. Hydraulic conductivities reported by Desaulniers et al. (1981) in similar materials near Wainfleet average approximately 3×10^{-10} m/s and several values in glaciolacustrine deposits near Lewiston, New York were also in the 10^{-10} m/s range (Wehran Engineering P.C. 1983). No drilled wells are known to obtain water from the confining layer.

The surficial, fractured portion of the confining layer may extend to depths which range up to several metres and occasional dug and bored wells reportedly obtain water supplies within this zone. Saturated fracture systems and granular laminations within the glaciolacustrine deposits are considered to be the source of water to such wells. In view of the fine-textured character of the deposits and the limited porosity of the fractures, yields to most shallow dug and bored wells are expected to be low and users likely rely on well-bore storage for periods of peak use.

Alluvium may provide water supplies to shallow dug and bored wells at some flood plain locations.

4.0 SITE GEOLOGY AND HYDROGEOLOGY

The following discussions of geology and hydrogeology at Site LF-9C take into account the regional data together with the new borehole information. In addition, data from hand auger holes and formal and informal field interviews are integrated into this analysis. Figure 4 (in map pocket)

provides locations of the cross-sections and the field data presented in this report.

Results from the GLAL borehole program are used to confirm the geology and hydrostratigraphy and the predictability and uniformity of subsurface conditions. Hydrogeologic discussions are based on the borehole geology and on such other sources of information as the water well records and water use data provided by local residents. Table 1 compares local geologic and hydrostratigraphic units for the site and the vicinity. This table provides the framework for the discussions that follow.

4.1 SITE GEOLOGY

Five continuously sampled boreholes were drilled to investigate the subsurface geology and were cored into dolomitic bedrock. Gartner Lee Associates Limited borehole locations are shown in Figure 4 along with water wells, oil and gas wells and field station sites (hand auger locations). Logs of GLAL boreholes and summaries of other subsurface data are included in Section 8.0. Cross-sections through the study area are presented in Figures 5 and 6 (in map pocket) and geologic descriptions on the sections are simplified for presentation. The geologic names on the borehole logs (e.g. Halton Till and upper glaciolacustrine unit) are used to relate local geology to the established regional geologic framework and are based on published descriptions.

TABLE 1: SUMMARY OF LOCAL GEOLOGIC AND HYDROSTRATIGRAPHIC UNITS

GEOLOGIC UNIT	HYDROSTRATIGRAPHIC UNIT	
UPPER GLACIOLACUSTRINE		FRACTURED ZONE (UPPER GLACIOLACUSTRINE)
HALTON TILL	CONFINING LAYER	UPPER GLACIOLACUSTRINE, HALTON TILL, LOWER GLACIOLACUSTRINE
LOWER GLACIOLACUSTRINE		
LOWER TILL		LOWER TILL
BASAL GRANULAR	BASAL GRANULAR AND BEDROCK AQUIFER	
BEDROCK		
GUELPH FORMATION		

Note: There are no known deposits of alluvium on this site.

4.1.1 TERRAIN

Site LF-9C is located on a portion of the Haldimand Clay Plain (Chapman and Putnam 1966). The plain is generally flat to gently rolling except where it is dissected by stream erosion, however these eroded valleys are relatively minor features on the landscape. There are numerous small, shallow depressions (approximately a metre deep) on the site which are poorly drained and contain standing water through much of the year. Elevations on site range from 186 m (above sea level) along the north and west portions of the site to 183 m along the south-central part of the site. The site drains to the Welland River. There are no known deposits of alluvium on the site.

4.1.2 BEDROCK GEOLOGY AND DRIFT THICKNESS

GLAL boreholes which were cored into rock encountered grey dolostone with occasional vugs and thin, shaley interbeds. These descriptions are similar to those provided by Telford et al. (1976) and are considered to indicate the Guelph Formation. The contact with the Salina Formation lies south of the site according to Telford et al (1976). The bedrock surface slopes generally southward across the study area with elevations of approximately 160 m in the north and 145 m in the south.

Drift or overburden thickness in the GLAL boreholes and the single onsite water well (for which a record is available) ranges from about 30 m to more than 35 m.

4.1.3 BASAL GRANULAR UNIT

No basal granular deposits were encountered in the GLAL boreholes, however water well records in the study area note the occurrence of sand and gravel deposits between the bedrock and the lower till. It is considered that the basal granular unit is discontinuous beneath the site and the study area.

4.1.4 LOWER TILL

A clayey to sandy silt lower till occurs between the bedrock and the lower glaciolacustrine unit (Figures 5 and 6). This lower till rests directly on bedrock and ranges in thickness from 0.8 to 3.3 m in the GLAL boreholes. It is typically dark greyish brown, very dense, saturated and shows minor variability in colour and texture between GLAL boreholes. Sand inclusions 8 and 24 cm thick occur within the till in Boreholes GL3 and GL5 respectively (Section 8.5) and are

considered to be lenses of local extent. Water well logs generally report 'stony clay', 'clay and/or gravel', and 'hardpan' between the clay and bedrock (Table 4, Section 8.1) and such deposits are inferred to be the lower till.

4.1.5 LOWER GLACIOLACUSTRINE UNIT

This unit ranges in thickness from 11.2 to 23.0 m in the GLAL boreholes and consists generally of laminated silty clay and clayey silt with occasional small pebbles (Section 8.5). Occasional "paper thin" to 1 cm thick laminae of silt to fine sand were observed within this unit and a 0.5 m thick bed of very fine sand was noted in Borehole GL1 at a depth of 21 m. These fine sandy deposits are considered to be discontinuous. The lower glaciolacustrine unit thins slightly in the central and southern parts of the site.

4.1.6 HALTON TILL

The Halton Till was encountered in all the GLAL boreholes and is typically a silty clay to clayey silt with small pebbles. It is massive to indistinctly laminated and commonly grades into both underlying and overlying glaciolacustrine units. The till varies between 0.4 and 3.6 m in thickness (Section 8.5). The laminations and gradational contacts suggest a waterlain origin. This interpretation is consistent with the geologic history of the region proposed by Feenstra (1981).

4.1.7 UPPER GLACIOLACUSTRINE UNIT

This unit is typically a brown to dark grey silty clay to clayey silt with occasional small pebbles less than a centimetre in size. It is usually laminated with reddish and grey layers but may contain massive zones. A subtle colour

change occurs from brown to grey brown or grey between depths of 3 to 6 m. The upper 1 to 3 m is more intensely weathered and rarely shows visible laminations. Fracture frequency decreases rapidly with depth and fractures are infrequent below about 5 m. The deepest evidence of fracturing was noted in Borehole GL3 at a depth of 10.2 m (Section 8.5). Grey carbonate infilling (with a clay-like texture) was observed in many fractures. Gypsum and/or calcite crystals were also occasionally noted along other fractures. Occasional silt laminations and a single sand seam (Borehole GL1) were observed in the samples and in most cases these were 'paper thin' and barely visible. The upper glaciolacustrine unit ranges in thickness from 6.5 m in Borehole GL2 to 20.0 m in Borehole GL1. This unit appears to be thickest in the central and southern portions of the site.

4.1.8 DISCUSSION

The combined thickness of the three silt-clay units is approximately 30 m across the site, although the thicknesses of the individual units vary. No significant or continuous granular zones occur within the silt-clay sequence and it exhibits a high degree of textural uniformity. The lower till ranges up to 3 m in thickness and varies texturally from a clayey silt to a sandy silt.

4.2 SITE HYDROGEOLOGY

The Phase 4A field work combines first-hand geologic descriptions and interpretations with the existing data bases which consist primarily of water well record information. Hydrogeologic analyses utilize the geology, the water well

records, information obtained from the public, information supplied by researchers in similar hydrogeologic settings, and the experience of Gartner Lee Associates Limited staff. Descriptions of the hydrostratigraphic units, flow systems, ground water use, and potential contaminant pathways are presented in the following sections.

4.2.1 HYDROSTRATIGRAPHY

Two major hydrostratigraphic units are present at Site LF-9C. These are (1) an aquifer which consists of the upper bedrock and associated granular deposits, and (2) a confining layer which extends from surface to the first significant granular unit or to bedrock. Confining layer thicknesses for the study area and the site are presented in Figure 7 (in map pocket).

4.2.1.1 Bedrock and granular aquifer

The bedrock is the most important source of water to drilled wells in the study area. The fractured upper portion is considered to constitute a permeable zone which is a preferred avenue for lateral ground water flow. The consistency with which adequate water supplies are encountered within the upper few metres suggests that horizontal fracturing is well developed, however the reported ranges in pumping rates and drawdowns suggests that fracture development is variable. The thickness of the fractured zone is considered to be about 5 m, the average hydraulic conductivity is estimated to be 5×10^{-5} m/s based on local water well record data and analytical procedures described by Walton (1962) and Ogden (1965). The average porosity is considered to be about 0.01 and the average lateral gradient is estimated to be approximately 0.01 based on reported static water levels in

wells and on estimated well elevations. Approximately 20% of the well records in the study area report granular materials above the bedrock and water supplies have been developed at most of these locations. The only drilled well on the site for which a water well record is available obtains water from gravel at a depth of about 35 m. The bedrock and adjacent granular deposits are considered to be in good hydraulic connection and ground water flow is considered to occur primarily through the bedrock because of the discontinuous nature of the granular aquifer.

4.2.1.2 Confining layer

The confining layer on the site extends from the surface to bedrock based on the GLAL boreholes. The confining layer is characterized by fine-textured materials which have low hydraulic conductivites. It includes three hydrostratigraphic subunits which include (1) the lower till, (2) the lower glaciolacustrine unit, The Halton Till and the unfractured upper glaciolacustsrine unit and (3) the fractured, surficial portion of the upper glaciolacustrine unit. Each of these subunits is discussed and described in the following paragraphs. Table 2 summarizes the thicknesses of each of the confining layer components and selected hydrogeologic parameters of each.

The lower till was encountered in the five GLAL boreholes and is also reported in Ministry of the Environment water well records where it is described as 'stony clay', 'clay and gravel', and 'hardpan'. The lower till ranges in thickness from 0.8 to 3.3 m in the GLAL boreholes. It is not known to be a source of water supply and is included as part of the confining layer. It consists

TABLE 2: SUMMARY OF CONFINING LAYER CHARACTERISTICS

BOREHOLE / PARAMETER	THICKNESS OF CONFINING LAYER SUB-UNITS			THICKNESS OF CONFINING LAYER
	LOWER TILL (m)	UNFRACTURED GLACIOLACUSTRINE UNITS AND HALTON TILL (m)	SURFICIAL FRACTURED ZONE (m)	(m)
GL1	3.2	26.6	5.0	34.8
GL2	0.8	24.3	5.0	30.1
GL3	1.3	27.5	5.0	33.8
GL4	3.3	26.1	5.0	34.4
GL5	1.0	27.6	5.0	33.6
Average Hydraulic Conductivity m/s	$1x10^{-8}$	$3x10^{-10}$	$1x10^{-8}$	
Average Porosity	0.3	0.5	0.0001	

Notes:

- Unfractured porosity values are estimates of total intergranular porosity
- The fractured porosity value is the effective fracture porosity reported by Desaulniers (1982)
- Porosity values in the unfractured materials reflect intergranular porosity. Additional fracture porosity is present in the fractured zone. These fractures are accompanied by increased hydraulic conductivities with the result that ground water can potentially move more rapidly along fractures.

of silt in four GLAL boreholes (Section 8.5) and clayey silt in a fifth. Inclusions of sand (8 to 24 cm thick) were encountered within the lower till in Boreholes GL3 and GL5, however these are considered not to have lateral continuity. Based on textural considerations, the average hydraulic conductivity of the lower till is estimated to be about two orders of magnitude greater than that of the overlying glaciolacustrine and Halton Till deposits. This value ($1x10^{-8}$ m/s) falls within the range for glacial till given by Freeze and Cherry (1979). The porosity is considered to be approximately 0.3 and is slightly less than the value applied to the clayey glaciolacustrine and Halton Till deposits to reflect the silty and sandy textures of the lower till.

The lower glaciolacustrine unit, the Halton Till and the unfractured portion of the upper glaciolacustrine unit comprise the hydrostratigraphic subunit with the lowest hydraulic conductivity in the study area. This subunit is present in all GLAL boreholes and ranges from approximately 24 to 28 m in thickness (Table 2). Hydraulic conductivities are considered to be similar to values reported by Desaulniers et al. (1981) in fine-textured deposits near Wainfleet. These values range from $1.1x10^{-10}$ to $8.2x10^{-10}$ m/s for laboratory tests and from $1.3x10^{-10}$ to $7.9x10^{-10}$ m/s for in situ tests. The overall geometric mean is approximately $3x10^{-10}$ m/s. Porosities ranged from 0.34 to 0.60 at Wainfleet and the approximate average of this range (0.5) is applied to this unit at Site LF-9C. Laboratory and field testing of similar fine-textured glaciolacustrine deposits near Lewiston, New York yielded a range of hydraulic conductivities from $1.4x10^{-10}$ to $8.7x10^{-10}$ m/s over depths from 4.7 to 10.0 m (Wehran Engineering, P.C. 1983).

The upper 1 to 2 m (approximately) of the confining layer is most severely fractured; however, fracture frequency declines rapidly with depth and fractures become more tightly closed and fewer. Based on borehole logs (Section 8.5) it is estimated that fracturing is generally limited to depths of about 5 m or less and while occasional fractures are noted at greater depths, they are rare. The deepest fracture noted on the site is at approximately 10 m in Borehole GL3. Freeze and Cherry (1979) note that clayey or silty tills and glaciolacustrine deposits in southern Ontario contain networks of hairline fractures which are essentially vertical and which are responsible for hydraulic conductivities one to three orders of magnitude greater than in unfractured materials. Based on this observation, the fractured zone is assigned a hydraulic conductivity of 1×10^{-8} m/s which is approximately two orders of magnitude greater than the underlying unfractured deposits. The surficial fractured zone is included within the confining layer because it is part of the upper glaciolacustrine unit and is clayey and silty in texture. While the higher hydraulic conductivity is applied over a 5 m interval, fracturing is considered significant only in the upper 1 to 1.5 m, as deeper fractures are more tightly closed and fewer in number. Desaulniers (1982) reports an effective fracture porosity of 0.0001 in fine-textured deposits in Lambton County. These deposits are considered texturally similar to materials at this site and this porosity value is considered to be applicable here.

4.2.1.3 Discussion

The confining layer at Site LF-9C is approximately 30 to 35 m thick. The site is characterized by uniform and

predictable hydrogeologic conditions and there is a strong likelihood of encountering similar conditions at other locations on the site.

4.2.2 GROUND WATER FLOW REGIME

Infiltration is the source of ground water and differences in hydraulic head provide the driving force for ground water flow systems. At the site, a shallow lateral flow system is considered to exist in the saturated portion of the fractured zone. A deeper flow system slowly transports small amounts of ground water down and through the confining layer and another, primarily lateral flow system occurs within the upper bedrock and associated granular deposits. The site is located in an area where hydraulic gradients in the confining layer are downward. This condition is indicated by a water table which is close to the surface and by water levels in the underlying aquifer which are several metres below ground level. Flow systems are discussed below and estimates of flow rates are provided for comparative purposes.

The water table occurs in the fractured zone and its shape is a reflection of topography. Fracturing and ground water flow diminish rapidly to the base of the fractured zone which extends to a depth of about 5 m on the site. The shallow flow system is most active near the surface where fracturing is most common and where fracture permeability is best developed. Movement in the shallow flow system is essentially lateral and rates and directions of flow are dependent on elevation differences in the water table. Desaulniers et al. (1981) notes that shallow ground waters below depths of 3 to 4 m in fine-textured materials near

Wainfleet were recharged prior to the early 1950s based on tritium analyses. The average lateral flow rate in the fractured zone at Site LF-9C is about 10 m per year based on an approximate gradient of 0.003, an average hydraulic conductivity of 1×10^{-8} m/s and an average fracture porosity of 0.0001. Sample calculations of flow rate employing Darcy's Law are provided in Section 8.6. Estimated fracture flow rates are usually large relative to flow rates in granular materials because of large differences in porosity. Fracture flow predictions may be unrealistically large if the rates are interpreted as 'straight-line' pathways because fractures may be complex and interconnections indirect. The quantity of flow in the shallow system is greatest when the water table is closest to ground level and the saturated zone is thickest. Flow rates are much less in the unfractured portion of the confining layer.

Hydraulic gradients in the unfractured portion of the confining layer are downward, however flow rates and amounts of flow are very small. The average gradient in wells in the site vicinity (based on static levels reported in water wells at the time of their construction) is about 0.3. In calculating gradients, the water table was selected at ground level to provide a maximum head differential or driving force across the confining layer. Hydraulic gradients measured by Desaulniers et al. (1981) near Wainfleet were vertically downward and ranged between 0.02 and 0.17 over depths to approximately 30 m in fine-textured deposits. Estimated downward flow rates through the three hydrostratigraphic subunits which comprise the confining layer are summarized in Table 3. Calculations are based on Darcy principles which are presented in Freeze and Cherry (1979)

and summarized in Section 8.6. Inspection of Table 3 indicates that estimated vertical flow rates in the fractured zone are between three and four orders of magnitude greater than in deeper portions of the confining layer and that the intermediate subunit of the confining layer (the unfractured glaciolacustrine deposits and the Halton Till) is the dominant unit which restricts ground water flow.

A more accurate assessment of ground water flow rates through the confining layer using advection and diffusion calculations is contained in Appendix A of the report entitled "Site Selection Process; Phase 4A, Selection of Preferred Site(s), Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

Desaulniers et al. (1981) concluded that pore waters at depth in fine textured deposits at Wainfleet (and other southwestern Ontario locations) originated approximately 8700 to 9800 years ago.

Ground water movement in the bedrock beneath the study area is generally southward. Static water level elevations in wells (Section 8.1) decrease irregularly from north to south and show a head differential of about 5 m across the study area which is equivalent to a gradient of about 0.01. Applying an average hydraulic conductivity of 5×10^{-5} m/s in the upper 5 m, and a porosity of 0.01, the ground water velocity in the bedrock is estimated to average about 5×10^{-5} m/s or 1600 m per year using Darcy's Law. This rate is considered unrealistically large as fracture interconnections are usually indirect and discontinuities are common.

TABLE 3: ESTIMATED VERTICAL FLOW RATES IN THE CONFINING LAYER

BOREHOLE	CONFINING LAYER		
	FRACTURED ZONE FLOW RATE (m/s	UNFRACTURED GLACIOLACUSTRINE UNITS AND HALTON TILL FLOW RATE (m/s)	LOWER TILL FLOW RATE (m/s)
GL1	$1x10^{-6}$	$2x10^{-10}$	$4x10^{-10}$
GL2	$1x10^{-6}$	$2x10^{-10}$	$4x10^{-10}$
GL3	$1x10^{-6}$	$2x10^{-10}$	$4x10^{-10}$
GL4	$1x10^{-6}$	$2x10^{-10}$	$4x10^{-10}$
GL5	$1x10^{-6}$	$2x10^{-10}$	$4x10^{-10}$

Notes:- Hydraulic conductivity and porosity estimates are provided along with thicknesses of the confining layer sub-units in Table 2.

- Multiply by $3.15x10^{7}$ for flow in metres per year.

4.2.3 GROUND WATER USE:

Water use information is based on water well records supplied by the Ministry of the Environment and on data supplied by residents and landowners on the site and on adjacent properties.

4.2.3.1 Availability

Water supplies for domestic, stock, and general agricultural purposes are obtained primarily from drilled wells and cisterns with occasional dug wells and ponds. Some cisterns are periodically replenished with trucked water and drinking water is occasionally imported from offsite locations. Water use information is summarized according to type of source in Figure 8 (in map pocket) and is supported by Table 6 (Section 8.3).

Based on water well records and field information surveys, the bedrock and basal granular deposits at the contact with the bedrock surface are sources of water supply to drilled wells in the study area. Test pumping rates during development are usually in the range of 0.8 to 1.4 litres per second (L/s) and drawdowns range from 0.3 to 4.5 m. Drilling contractors most frequently recommend pumping rates in the range of 0.6 to 0.9 L/s with pump settings between 15 and 20 m. In most cases, adequate supplies are obtained from the bedrock within the upper 2 to 3 m, although penetration depths up to 7 m are reported. The locations of wells which obtain water from basal granular deposits follow no apparent pattern. In one case the driller has reported sand and gravel but has cased through it to obtain supplies from the bedrock.

Several additional wells on and adjacent to the site were reported during field information surveys. These are mainly drilled wells which are similar in depth to those reported in the water well summary (Section 8.1) and which are used for domestic, stock, and general agricultural purposes. Two of the additional wells are on the site, both are located along Highway 20, and both are drilled. Two offsite dug or bored wells were identified during the field interviews (No. 3 and No. 15 in Figure 8). Number 3 is located immediately north of the site along Highway 20 and No. 15 is located approximately 1.5 km south of the site. Number 15 is reported to be 9.1 m deep but no depth is available for well No. 3 (Table 6). Both reportedly provide reliable supplies, and are considered to obtain water from silty laminations and from any fractures which may be present. Yields are considered to be relatively low and peak use is likely accommodated by storage.

Rainwater cisterns are a common source of additional water supply. Most cisterns 'dry up' periodically during periods of low rainfall and several are maintained with trucked water. Dugouts and off-stream ponds are also used for stock and agricultural purposes. It is considered that many dugouts penetrate the water table although some may rely on surface runoff. Most residents on the site and on adjacent properties rely on water supplies from more than one source. Eleven of the residences for which water use data are available (Table 6) use cisterns for some or all household puroses. Drilled and dug wells are the sole source of supply in three cases and provide agricultural and partial household needs in eight cases. There are only two dug wells reported near the site and a number of ponds are used for livestock watering.

4.2.3.2 Quality:

Ground water quality from the bedrock and from deep sand and gravel deposits near the bedrock contact is generally reported to be 'fresh'. Ministry of the Environment well records #422 and #2704 (Figure 4 and Section 8.1) report 'sulphurous' quality, however these are in the southeast portion of the study area in the direction of the Salina aquifer. Two additional drilled wells noted during the field interviews were also reported to be 'sulphurous' in quality (Figure 8; #4 and #14, Section 8.5). It is considered that while sulphurous water is not common in the study area, it does occur occasionally as the site and study area are relatively close to the Salina aquifer. Ground water from the Guelph aquifer is usually reported as being 'fresh'. Based on the "Walk and Talk" information, ground water from shallow dug and bored wells is reported as 'soft'.

4.2.4 POTENTIAL CONTAMINANT PATHWAYS:

In general, there are two pathways by which contaminants can potentially leave this site; these are (1) natural pathways along ground water flow systems and (2) man-made pathways which follow such structures as abandoned and unplugged wells and tile drains. The natural routes retard movement as a result of low hydraulic conductivity. Natural pathways are discussed in the sections on Site Hydrogeology (4.2.1) and Ground Water Flow Regime (4.2.2).

Efforts have been made to identify and locate man-made structures such as water wells, gas wells, drainage tiles, and excavations which are located on site. These structures could act as conduits or pathways to accelerate offsite ground water movement. For example, improperly sealed and abandoned

wells which penetrate the confining layer could provide rapid access for shallow ground water or surface water to move downward to the underlying aquifer. Shallow structures such as granular trench backfill and drainage tiles could provide offsite pathways for surface water and shallow ground water.

A total of three water wells are reported on the site based on the 'Walk and Talk' interviews. All three are believed to be in active use and all three are believed to penetrate the confining layer. Gas wells are common in the area and while Ministry of Natural Resources do not indicate any wells on the site, interview information suggests that a gas well was drilled near Highway 20 (#5 in Table 5, Section 8.3).

Approximately 19 ha of the 135 ha site is reported to be tile drained and most of this drainage is located in the southwest. The tile systems drain via local watercourses and ditches to the Welland River. The tiles are usually buried 1 to 2 m below the surface and spacings vary depending on local conditions. Tile drain information is contained in the 'Walk and Talk' information.

Excavations are believed to be limited to the immediate vicinity of buildings on the site and no extensive corridors of permeable backfill were identified from the field interviews.

5.0 GEOTECHNICAL CONSIDERATIONS

This section provides a preliminary assessment of Site LF-9C from a soils engineering point of view. The geologic setting is described in detail in Section 4.0 of this report.

The geologic data base is supplemented by standard penetration split spoon tests at 1.5 m intervals in each of the five GLAL boreholes. The standard penetration (N) values have been used as a guide in estimating the relative density and consistency of the various deposits. Shear strengths noted here are estimated from blow-count shear-strength relationships obtained from other studies in similar materials in the Niagara Peninsula. Moisture contents are also correlated with the standard penetration values on the geologic logs (Section 8.4). The geotechnical conditions at this site related to the geologic setting are described below.

A desiccated crust which is generally less than 7 m thick underlies the entire site. This crust exists in silty clay and has a generally very stiff to hard consistency based on N values that range between 15 and 39 (blows per 0.3 m). As such, the undrained shear strength varies from approximately 100 to greater than 200 kPa. The moisture contents in the desiccated crust were in the range of 14 to 26% indicating the material is drier than the plastic limit to about the plastic limit.

Geotechnically, the upper glaciolacustrine unit below the desiccated crust, the Halton Till, and the lower glacio-

lacustrine unit are similar. For this reason these deposits are treated as a single unit. This unit has a stiff consistency with N values in the 8 to 15 range except for Borehole GL1. In Borehole GL1, the clays have a very stiff consistency with N values up to 23. There is a tendency towards lower N values with depth, although there are some local fluctuations in individual boreholes. These values correspond to undrained shear strengths of 20 to 50 kPa with local zones approaching 100 kPa. In Borehole GL1, the undrained shear strengths typically range between 100 and 200 kPa. The moisture contents of these cohesive materials range between 13 and 38%. Generally, these cohesive soils are wetter than the plastic limit and there is a tendency towards increasing moisture content with depth. The lower till which overlies the bedrock is typically compact to very dense with N values which range from 17 to more than 50. In situ moisture contents were generally less than 10%.

Preliminary assessments based on data from the GLAL boreholes indicate that no significant soils engineering problems exist on the site provided that the guidelines suggested below are followed. It is considered that subsurface aspects can be handled with proper design and standard techniques. As a general guide, temporary excavations to about 10 m below ground surface present no significant problems if undertaken at 2:1 side slopes. Deeper excavations will have to be investigated in greater detail from a stress relief and stability perspective.

Treated waste residues could be placed to thicknesses of about 1.5 times the depth of the cells, based on a density of 1.35 tonnes per cubic metre without creating a surcharge

load. Provided there is no surcharge load within the cell base, settlement will be minimal. As well, no problems are anticipated with respect to bearing pressure. Greater thicknesses may be possible without creating a shear failure, but will require detailed investigation from a settlement and stability perspective. For the above-ground option, fills could be constructed to heights of about 15 m based on current data. For fills of this height, some settlement of the subsoils would be likely and would require detailed investigation. There is insufficient geotechnical information at this time to estimate the settlement which could occur.

The desiccated crust which underlies this site is generally very stiff to hard in consistency. The allowable bearing pressure in this crust is generally adequate for light to medium weight structures with shallow strip or conventional pad footings. As a guide, an allowable bearing pressure of 150 kPa can be adopted for footings founded in the upper 2 m of the desiccated crust. Provided that most of the applied foundation stresses are dissipated within the crust, settlement of these structures should be within tolerable limits.

For heavy structures, it will likely be necessary to transfer loads to the lower till or bedrock to obtain adequate bearing pressures. This aspect will require detailed foundation investigations during Phase 4B work on the preferred site.

The clayey subsoils on the site are workable. However, due to their 'wet' and 'sticky' nature, they will be a nuisance from a materials handling and trafficability perspective especially during wet weather.

6.0 SUMMARY

Site LF-9C is located on the Haldimand Clay Plain in West Lincoln Township. It is situated slightly north of the Salina-Guelph geologic contact and is underlain by dolostones of the Guelph Formation. Overburden varies from 30 to 35 m in thickness and consists of a lower silty till and clayey glaciolacustrine deposits separated by clayey Halton Till. There is evidence from water well records for a discontinuous basal granular deposit, however no such deposit was encountered in the GLAL boreholes. The two major hydrostratigraphic units are (1) a bedrock and granular aquifer and (2) a confining layer which usually extends from surface to the bedrock. The confining layer includes three subunits which are (i) the lower till, (ii) the lower glaciolacustrine unit, the Halton Till and the unfractured portion of the upper glaciolacustrine unit, and (iii) the surficial fractured portion of the upper glaciolacustrine unit. The confining layer is between 30 and 35 m in thickness and is considered to be uniform and predictable. Ground water movement in the surficial fractured zone is primarily lateral and is characterized by potential flow rates of approximately 10 m per year. Flow in the unfractured clayey portions of the confining layer is essentially vertical and occurs at rates of approximately 0.007 m per year. Flow in the lower till is also considered to be mainly vertical and occurs at a rate of about 0.01 m per year. Ground water movement in the bedrock is considered to be primarily lateral in a southerly direction and to occur primarily in the upper fractured zone at flow rates of about 1600 m per year.

Soils engineering at this site can be handled with proper design and standard techniques. Temporary excavations can safely extend to about 10 m below ground surface at 2:1 side slopes. Treated waste residues can be placed to thicknesses of about 1.5 times the depths of the cells. For the above-ground option, fill heights of about 15 m above ground surface will be stable. The desiccated crust beneath the site will support light to medium weight structures. However, for heavy structures it will likely be necessary to transfer loads to the lower till or to bedrock. Although the clayey subsoils are workable, their 'wet' and 'sticky' nature will create a nuisance from a materials handling and trafficability perspective.

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8.0 SUPPORTING INFORMATION

8.1 SUMMARY OF WATER WELL DATA (TABLE 4)

8.2 SUMMARY OF OIL AND GAS WELL DATA (TABLE 5)

8.3 SUMMARY OF SITE INTERVIEW (WALK AND TALK) DATA (TABLE 6)

8.4 FIELD STATION DESCRIPTIONS

8.5 BOREHOLE LOGS

8.6 SUPPORTING CALCULATIONS AND METHODS

8.7 GLOSSARY OF SELECTED TERMS

8.8 DETAILED FIELD METHODS

8.1 SUMMARY OF WATER WELL DATA

Water well locations are shown in Figure 4 (in map pocket).

Copies of original Water Well Records obtained from the Ministry of the Environment (MOE) were used for the following data summary and are on file.

Measurements, dimensions, and quantities on the Water Well Records are in Imperial units but are presented in metric units in the summary.

Water well locations (Figure 4) were plotted on 1:10 000 scale maps for this project and elevations were re-estimated based on the more accurate contours on these maps. Well elevations are above sea level (ASL) and are estimated to the nearest metre.

Wells are arranged in numerical order.

TABLE 4, SUMMARY OF WATER WELL DATA Site: LF-9C

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
422	Bozog, M. Con. 1, Lot 21 West Lincoln Twp. (Formerly Gainsborough Twp.)	180	Mar 1949	15.9		Slightly Sulphurous and Salty	42.1	4.3			Stock and Domestic	0.0 42.1	42.1 42.7	Sand, Gravel Rock
430	Beliak, S. Con. 2, Lot 16, West Lincoln Twp. (Formerly Gainsborough Twp.)	182	May 1964	15.9	34.4	Fresh	33.8	4.6	9.1	0.8	Stock	0.0 33.8	33.8 34.4	Blue Clay Grey Shale
431	Gracey, C. Con. 2, Lot 16 West Lincoln Twp. (Formerly Gainsborough Twp.)	177	Aug 1958	12.7	36.3	Fresh	36.3	0.6	0.6	1.3	Stock and Domestic	0.0 36.3	36.3 36.6	Clay Shale

TABLE 4, SUMMARY OF WATER WELL DATA Site: LE-9C

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN	DATE DRILLED YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
445	Wright, R. Con.3, Lot 15 West Lincoln Twp. (Formerly Gainsborough Twp.)	185	May	1967	15.9	34.8	Fresh	31.7	9.8	2.2	0.8	Stock and Domestic	0.0 31.4	31.4 34.8	Brown Clay Grey Limestone
446	Beamer, C., Con. 3, Lot 19, West Lincoln Twp. (Formerly Gainsborough Twp.)	186	Sep	1962	15.9	35.1	Fresh	34.1	9.1	12.2	0.8	Stock and Domestic	0.0 34.1	34.1 35.4	Blue Clay Grey Limestone
447	Veandermeulen, J., Con. 3, Lot 20 West Lincoln Twp. (Formerly Gainsborough Twp.)	183	Dec	1960	15.9	37.2	Fresh	36.6	7.6	13.7	0.8	Stock and Domestic	0.0 36.6	36.6 37.2	Clay Limestone
448	Boradyn, A., Con. 3, Lot 20, West Lincoln Twp. (Formerly Gainsborough Twp.)	186	Dec	1967	15.9	33.8	Fresh	33.8	9.1	10.7	1.2	Stock	0.0 29.0 32.9	29.0 32.9 33.8	Clay Clay, Gravel Gravel

TABLE 4, SUMMARY OF WATER WELL DATA Site: LF-9C

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
449	Crowe, N. Con. 3, Lot 21 West Lincoln Twp. (Formerly Gainsborough Twp.)	185	Oct 1960	15.9	37.5	Fresh	37.5	7.0	7.6	0.8	Stock and Domestic	0.0 9.1	9.1 37.5	Clay Red Sandy, Clay
466	Sarantakos, O., Con. 4, Lot 16 West Lincoln Twp. (Formerly Gainsborough Twp.)	187	Sep 1964	15.9	30.2	Fresh	29.3	9.1	9.8	1.2	Stock	0.0 29.0	29.0 31.4	Blue Clay Limestone
467	Skladas, J. Con. 4, Lot 16 West Lincoln Twp. (Formerly Gainsborough Twp.)	187	Jul 1966	15.9	32.3	Fresh	31.4	6.7	7.6	0.8	Stock	0.0 9.1 31.1	9.1 31.1 32.6	Brown Clay Blue Clay Grey Limestone
468	Morris, R. Con. 4, Lot 18 West Lincoln Twp. (Formerly Gainsborough Twp.)	185	Dec 1965	15.9	34.4	Fresh	32.9	8.5	11.6	1.1	Stock	0.0 29.9 32.3	29.9 32.3 32.4	Clay Clay, Gravel Niagara Rock
469	Beamer, O., Con. 4, Lot 19, West Lincoln Twp. (Formerly Gainsborough Twp.)	186	Jun 1954	14.3	29.6	Fresh	27.7	9.1	9.1	1.3	Stock	0.0 27.7	27.7 29.6	Clay, Boulders Niagara Rock

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LE-9C

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN	DATE DRILLED YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
470	Yoromich, P. Con. 4, Lot 21 West Lincoln Twp. (Formerly Gainsborough Twp.)	186	Oct	1967	15.9	34.4	Fresh	34.4	8.2	8.5	1.2	Stock and Domestic	0.0 24.4 33.5	24.4 33.5 34.4	Grey Clay Grey Clay, Gravel Gravel, Sand
1794	Katsoulis, A. Con. 4, Lot 20, West Lincoln Twp. (Formerly Gainsborough Twp.)	188	May	1968	15.9	36.6	Fresh	35.1	8.8	10.7	0.8	Domestic and Stock	0.0 7.3 32.9 35.1	7.3 32.9 35.1 36.9	Brown Clay Blue Clay Blue Clay, Gravel Grey Limestone
1888	Vandervelde, H. Con. 4, Lot 16 West Lincoln Twp. (Formerly Gainsborough Twp.)	187	Aug	1968	15.9	30.2	Fresh	29.6	9.5	19.8	0.8	Domestic and Stock	0.0 4.6 13.7 29.3	4.6 13.7 29.3 30.5	Brown Clay Blue Clay Red Clay Grey Limestone
1867	Flameling, Y. Con. 3, Lot 17 West Lincoln Twp. (Formerly Gainsborough Twp.)	185	Apr	1969	15.9	35.1	Fresh	35.1	9.1	12.8	0.8	Domestic and Stock	0.0 12.2 33.5 34.8	12.2 33.5 34.8 35.1	Brown Clay Red Clay Sand, Packed Gravel
1947	Visser, A. Con. 5, Lot 14, West Lincoln Twp. (Formerly Gainsborough Twp.)	187	Sep	1969	15.9	26.8	Fresh	25.4	10.7	15.2	1.5	Domestic and Stock	0.0 3.1 22.9 25.6	3.1 22.9 25.6 27.4	Brown Clay Blue Clay Clay, Gravel Limestone

TABLE 4, SUMMARY OF WATER WELL DATA Site: LF-9C

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
1961	Augustyn, A. Con. 2, Lot 18, West Lincoln Twp. (Formerly Gainsborough Twp.)	183	Dec 1969	15.9	39.6	Fresh	39.9	10.7	11.6	1.1	Domestic and Stock	0.0 31.1 35.1 39.6	31.1 35.1 39.6 39.9	Clay Stones Sand and Gravel, Packed Rock
2004	Skladas, J. Con. 4, Lot 16 West Lincoln Twp. (Formerly Gainsborough Twp.)	187	Aug 1970	15.9	30.8	Fresh	29.9	11.6	13.7	0.8	Domestic and Stock	0.0 6.7 23.8 29.9	6.7 23.8 29.9 30.9	Brown Clay, Packed Blue Clay, Soft Red Clay, Pebbles Grey Limestone, Layered
2124	Fois, H. Con. 2, Lot 17, West Lincoln Twp. (Formerly Gainsborough Twp.)	178	Oct 1971	15.9	40.2	Fresh	36.0	8.5	29.0	0.5	Stock	0.0 6.7 19.8 27.4 35.1 36.0	6.7 19.8 27.4 35.1 36.0 40.2	Brown Clay, Packed Grey Clay, Soft Red Clay, Soft Brown Clay, Gravel, Hard Grey Hardpan, Gravel, Hard Grey Rock, Layered
2164	Boulton, Ron Con.4, Lot 19 West Lincoln Twp. (Formerly Gainsborough Twp.)	187	Apr 1972	15.9	26.2	Fresh	26.5	9.8	9.8	0.8	Domestic	0.0 3.1 22.9 24.4 25.9	3.1 22.9 24.4 25.9 26.5	Brown clay Blue Clay Stones, Clay Stones, Gravel Rock
2306	Grant E. Con. 2, Lot 16, West Lincoln Twp. (Formerly Gainsborough Twp.)	178	Aug 1973	15.9	34.7	Fresh	34.8	6.1	11.6	1.2	Stock	0.0 25.9 34.4	25.9 34.4 34.8	Grey Clay Red Clay, Gravel Shale and Gravel

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-9C

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2330	Beamer, K. Con.3, Lot 19, West Lincoln Twp. (Formerly Gainsborough Twp.)	185	Dec 1973	15.9	32.3	Fresh	32.3	9.1	13.7	0.8	Domestic	0.0	11.6	Brown Clay, Packed
												11.6	31.7	Red Clay, Soft
												31.7	32.3	Grey Shale, Broken
2348	Vandervelde, E., Con. 4, Lot 20 West Lincoln Twp. (Formerly Gainsborough Twp.)	185	Mar 1974	15.9	33.5	Fresh	32.2	8.5	13.7	0.8	Domestic	0.0	9.8	Brown Clay, Packed
												9.8	28.7	Red Clay, Soft
												28.7	32.0	Grey Clay, Gravel Hard
												32.0	33.8	Grey Limestone, Layered
2391	Kapellas, A., Con. 3, Lot 16, West Lincoln Twp. (Formerly Gainsborough Twp.	186	Sep 1975	15.9	30.5	Fresh	30.5	11.6	12.2	-	Domestic	0.0	29.9	Grey Clay
												29.9	30.5	Shale
2531	Baradyn A. Con. 3, Lot 20 West Lincoln Twp. (Formerly Gainsborough Twp.)	186	Jun 1976	15.9	33.8	Fresh	33.8	9.8	12.2	1.1	Domestic and Stock	0.0	1.5	Brown Clay, Packed
												1.5	9.1	Grey Clay, Dense
												9.1	32.0	Brown Clay, Packed
												32.0	32.9	Brown Clay, Gravel, Packed
												32.9	33.8	Grey Shale, Layered
2704	Boverhof, J., Con. 2, Lot 22 West Lincoln Twp. (Formerly Gainsborough Twp.)	182	Sep 1978	15.9	49.4	Sulphurous	42.7	7.6	7.9	1.1	Domestic and Stock	0.0	40.2	Brown Clay, Dense
												40.2	42.7	Brown Clay, Gravel Packed
												42.7	49.7	Grey Limestone, Layered

TABLE 4, SUMMARY OF WATER WELL DATA Site: LF-9C

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2729	Tency Poultry Farms Limited Con. 4, Lot 16, West Lincoln Twp. (Formerly Gainsborough Twp.)	186	Nov 1978	15.9	31.7	Fresh	31.1	10.7	14.6	1.5	Domestic	0.0	28.0	Grey Clay
												28.0	30.5	Clay, Gravel
												30.5	31.7	Niagara Rock
2755	Devries, R., Con. 4, Lot 16, West Lincoln Twp. (Formerly Gainsborough Twp.)	186	Apr 1979	15.9	29.6	Fresh	29.6	9.5	13.7	1.1	Stock	0.0	9.1	Grey Clay, Packed
												9.1	29.1	Brown Clay, Dense
												29.1	29.4	Grey Shale, Layered
												29.4	31.7	Grey Limestone, Layered

8.2 SUMMARY OF OIL AND GAS WELL DATA

Oil and gas well locations are shown in Figure 4 (in map pocket).

Copies of original oil and gas well records were obtained from the Ministry of Natural Resources (MNR) office in London, Ontario. Additional locations of abandoned oil and gas wells were obtained from the MNR and from local residents and numbered 1-6 in Figure 4. There is no information available (aside from location) for these wells.

Imperial units are used in the original well logs and these have been changed to metric units in the summary. Where ground elevations are supplied, they have been verified using contours on 1:10 000 scale maps. Where no elevations were supplied, elevations are estimated from the base maps. All elevations are above sea level (ASL) and are shown to the nearest metre.

Copies of oil and gas well records and mapping are on file.

TABLE 5, SUMMARY OF OIL & GAS WELL DATA Site: LF-9C

WELL BOREHOLE No.	LOCATION location	GROUND ELEVATION (m ASL)	FROM FROM	TO TO	MATERIALS DESCRIPTION	COMMENTS
172-4289	Con. 2, Lot 17 West Lincoln R.M. of Niagara	179	0.0 36.0	36.0 160.0	Overburden Bedrock	Gas Producer
172-4632	Con. 2, Lot 17 West Lincoln Twp. R.M. of Niagara	178	0.0 30.5	30.5 161.2	Overburden Bedrock	Gas Producer
193-5489	Con.3, Lot 19 West Lincoln Twp. R.M. of Niagara	185	0.0 30.8	30.8 159.0	Overburden Bedrock	Gas Producer
1 TO 6	Various					No data available, locations from MNR Petroleum Resources Map F-16 (effective date February, 1984)

Note: Data for above wells condensed from records on file with Ministry of Natural Resources, (MNR), London, Ontario.

8.3 SUMMARY OF SITE INTERVIEW DATA

Water use data from Ecologistics Limited field interview (Walk and Talk) forms is presented in Figure 8 (in map pocket). Water use data were collected from residents on the site and on adjacent properties.

Water use data are augmented with information collected by Gartner Lee Associates Limited staff during discussions with local interest groups. Deeper drilled wells are considered to terminate in bedrock where supporting evidence is available.

Although most of the information was provided in Imperial units, it has been converted to metric units for uniformity with the remainder of the report.

Interview numbers are related to identifications assigned by Ecologistics Limited during the collection of these data.

Copies of the interview forms are on open file with the Ontario Waste Management Corporation.

West Lincoln Township was formerly Gainsborough Township.

A copy of the water resources form is included at the end of this section.

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site LF-9C Sheet 1 of 5

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
1	Wm. Devries	17 West Lincoln Twp.	3	478-G			✓	Cistern supplies household, - water quality is soft - goes dry 8 times per year
2	Mr. & Mrs. C. Huizinga	17 West Lincoln Twp.	4	220-2			✓	Cistern supplies household - bottled water - pond on property
3	Mr. & Mrs. Q. Chou	17 & 18 West Lincoln Twp.	4	223-2		✓		Dug/bored well (No MOE record) - supplies household and livestock Pond on property - 0.6 m (2 ft) deep
4	Mr. C. Tsiantoulas	18 West Lincoln Twp.	4	118-2	✓✓		✓	Cistern supplies household - water purchased from Welland Drilled well (MOE well 468) - over 30.5 m (100 ft) deep - supplies livestock, never gone dry - water sulphurous Drilled well (No MOE Record) - over 30.5 m (100 ft) deep - supplies livestock, never gone dry - water sulphurous Pond supplies livestock and household

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site LF-9C Sheet 2 of 5

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
5	Morningstar Bros.	17 & 18 West Lincoln Twp.	3	38-2	✓			Drilled well (No MOE record) - supplies household and livestock - never goes dry Gas/oil well on property, well #6 in Figure 4.
6	Mr. & Mrs. J. Melon	18 West Lincoln Twp.	3	97-2	✓		✓	Cistern supplies household - soft water Drilled well (No MOE Record) - 30.5 m (100 ft.) deep - supplies livestock - hard water quality Pond on property
7	Mr. & Mrs. K Beamer	19 West Lincoln Twp.	3	119-2	✓		✓	Drilled well (MOE well 2330) - 32.3 m (106 ft.) deep - supplies household, hard water quality Cistern supplies household - soft water quality
8	Clarence A. Beamer	19 & 20 West Lincoln Twp.	3	87-2	✓		✓	Drilled well (MOE well 446) - 34.1 m (112 ft) deep - supplies household and livestock - hard water quality, good drinking water Cistern supplies household Pond on property never goes dry Water level drop to 9.1 m (30 ft) from 4.9 m (16 ft.) because of gravel pit

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site LF-9C Sheet 3 of 5

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
9	Mr. Ross Allen	17 West Lincoln Twp.	2	548			✓	Cistern supplies household - rainwater Bottled water
10	Mr. & Mrs. S. Kszan	17 West Lincoln Twp.	3	96-2	✓		✓	Cistern supplies household - soft water quality, never goes dry Drilled well (No MOE record) - supplies livestock, never goes dry - fresh water Pond on property
11	Mr Y. Flamling	17 West Lincoln Twp.	3	N/A	✓		✓	Drilled Well (MOE well 1867) - 35.1 m (115 ft.) deep - supplies household and livestock - water quality hard Cistern supplies household Pond on property (behind barn) Pond on property south of residence (GLAL field info.)
12	Mr, P. Maylott	19 West Lincoln Twp.	3	110-A			✓	Cistern supplies household and livestock - water trucked in - water quality good, hard, (mainly rain water) - occasional runs dry - cistern brick lined 4.6 m (15 ft deep, 1.5 m (5 ft.) wide

Table 8 SUMMARY OF SITE INTERVIEW DATA

Site LF-9C Sheet 4 of 5

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
13	Hans Dick	19 West Lincoln Twp.	3	88-2	✓✓		✓	Cistern supplies household - water quality soft (rainwater) - goes dry once every 5 years Drilled well (No MOE record) -37.8 m (124 ft.) deep in front of barn - supplies livestock, never gone dry - water level was down 12.2 m (40 ft.) 5 years ago when canal work was being done - water quality hard, sulphurous Drilled well (no MOE record) - 37.2 m (122 ft.) deep, beside barn - supplies livestock, small capacity - water quality hard, sulphurous
14	Peter Schuender	19 West Lincoln Twp.	2	8-2	✓		✓	Drilled well (no MOE record) - 39.6 m (130 ft.) deep - water level 7.6 m (25 ft.)from ground level - water found at 39.6 m (130 ft.) - supplies household - water quality hard, sulphurous high iron content - water must go through water softener before use - well never gone dry - well drilled by Wray Field, Vineland Cistern supplies household Pond on property spring fed - was used for barn, not used now

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site LF-9C Sheet 5 of 5

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
15	Ms. Norma-Jean Vitucci	20 West Lincoln Twp.	2	468-G		✓		Dug/bored well (No MOE record) - 9.1 m (30 ft.) deep - supplies household - water quality soft Pond on adjacent property - supplies household - water quality soft - water level gets low 1 year in 8
16	Mr. John Murdock	15 West Lincoln Twp.	4	557				No information provided
17	Mr. George Miller	16 West Lincoln Twp.	4	556				No information provided

WATER RESOURCES FORM

Interview Identification Number: _____

PHYSICAL RESOURCES - WATER

We are interested in the water used on this property: where it comes from, its quality, and how much you use.

1. What is this household's source of supply for domestic water? (e.g., drinking, laundry, toilet)

drilled water	☐	Locate on map with symbol Dr-H
dug wells	☐	Locate on map with symbol Du-H
stream water	☐	Locate on map with symbol *SW-H
cistern	☐	Locate on map with symbol *C-H
bottled water	☐	
municipal main	☐	
other, specify		_____

2. What is the water supply for the livestock and irrigation on this property?

drilled wells	☐	Locate on map with symbol Dr-A
dug wells	☐	Locate on map with symbol Du-A
streams or dams	☐	Locate on map with symbol *SW-A
cisterns	☐	
municipal main	☐	
other (e.g., ponds)		_____

3. Are there any streams or ponds on your property?

streams	Yes ☐	No ☐
ponds	Yes ☐	No ☐

4. What can you tell us about the quality of the water

a) you use or drink? (hard, soft, sulphurous, iron, salty, etc.) _____
_____
_____

b) in the streams or ponds? _____
_____
_____

5. Do the wells, cisterns or streams that you use for water supply ever go dry? If so, how often? _____
_____
_____
_____

Interview Identification Number: _____

6. Can you tell us anything about the construction of the wells? (e.g., when they were drilled, depth, type of pump, name of the driller) _____

7. Has any portion of your property been filled or excavated? If so, please show where on the map. (Locate on map with symbol EV.)

8. Do you know where there are any gas or oil wells on your property or the property you farm - in use or abandoned? Please show their locations on the map with the symbol GW.

9. Please tell us about any problems with flooding in the creeks and streams on your property. Please show locations of the flooded areas on the map. (Locate with symbol FA.) _____

8.4 FIELD STATION DESCRIPTIONS

Field stations are located in Figure 4 (in map pocket) and are sites where hand auger holes were constructed.

A standard 25 mm soils auger was used to examine soil properties.

No samples were collected at field stations.

8.4 FIELD STATION LOGS, SITE LF-9C

Field Station #1:

Hand auger hole

0-0.3 m	fibrous, woody organics in a silt matrix
0.3-0.6 m	dark brown, silty clay, trace of roots
0.6-1.5 m	medium grey clay, trace of roots at 0.9-1.1 m and trace of silt 1.2 to 1.5 m, wetter than plastic limit

Field Station #2:

Hand auger hole

0.0-0.3 m	medium grey clay with a trace of silt (standing water in the area)

Field Station #3

Hand auger hole

0.0-0.3 m	fibrous to woody organics in a silt matrix dark grey
0.3-0.6 m	brown grey clay with silt, wetter than plastic limit
0.6-1.5 m	medium grey clay, trace of silt, wetter than plastic limit - water level 0.05 m below surface

Field Station #4:

Hand auger hole

0.0-0.6 m	grey clay, contains roots at 0.0-0.3 m oxidized, wetter than plastic limit
0.6-0.9 m	medium grey to dark grey clay, wetter than plastic limit
0.9-1.4 m	dark grey to blue grey clay, wetter than plastic limit
1.4-1.5 m	medium grey to light grey clay, trace of silt, wetter than plastic limit
1.5-1.7 m	light grey to medium grey clay, wetter than plastic limit
1.7-1.8 m	light grey to light brown-grey clay, wetter than plastic limit
1.8-2.3 m	grey clay, wetter than plastic limit
2.3-2.4 m	red brown to grey clay, wetter than plastic limit

Field Station #5

Hand auger hole

0.0-0.3 m	topsoil, roots, silty
0.3-0.5 m	brown-grey clay
0.5-0.8 m	grey clay, about plastic limit
0.8-1.2 m	grey clay, wetter than plastic limit

8.5 GARTNER LEE ASSOCIATES LIMITED BOREHOLE LOGS

Borehole locations are shown in Figure 4 (in map pocket)

Borehole logs are based on field notes which have been verified by the project geologist following re-examination of the samples.

Continuous samples were obtained by advancing a large split tube (8.9 cm x 152 cm) through the hollow stem augers.

Standard penetration tests were performed at 1.5 m intervals and water contents were measured in samples taken from the 'nosepiece' of the standard split spoon sampler.

Textural descriptions are provided for each geologic unit and each is named to indicate its origin.

Borehole elevations are estimated from the 1:10 000 scale base map contours. All elevations are above seal level (ASL) and are estimated to the nearest metre.

All material descriptions are based on visual hand sample examination and no laboratory grain size analyses were performed. Textural descriptions are provided under 'Partical Site Classification System' in the Glossary of Selected Terms, Section 8.7.

Borehole elevations are estimated from the 1:10 000 scale base map contours. All elevations are above sea level (ASL) and are estimated to the nearest metre.

The term pebble has been used to describe gravel sized rock particles within a fine grained matrix.

GEOTECHNICAL NOTES AND ABBREVIATIONS

Standard Penetration Resistance 'N' - The number of blows required to advance a standard split spoon sampler 30 cm into the subsoil, driven by means of a 63.5 kg hammer falling freely a distance of 75 cm.

The consistency of cohesive soils and the relative density or denseness of cohesionless soils are described as follows:

Consistency	'N' Blows per 0.3 m	Denseness	'N' Blows per 0.3 m
Very soft	0-2	Very Loose	0-4
Soft	2-4	Loose	4-10
Firm	4-8	Compact	10-30
Stiff	8-15	Dense	30-50
Very Stiff	15-30	Very Dense	> 50
Hard	> 30		

ABBREVIATIONS

WTPL - Wetter than Plastic Limit

DTPL - Drier than Plastic Limit

APL - About Plastic Limit

Wp - Plastic Limit

WL - Liquid Limit

SS - Split Spoon Sample

T - Split Tube Sample

BOREHOLE NO. GL 1 (9C)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** September 4, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** EJK/AC

GROUND ELEVATION 185m (approximately) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
0.3	TOPSOIL: dark greyish brown clayey silt to silt topsoil with roots and vegetation								
	CLAYEY SILT TO SILTY CLAY: dark greyish brown to brown clayey silt to silty clay, generally well laminated with massive zones, red and grey laminations, occasional thin (<1 mm) silt laminae, occasional small (<1 cm) pebbles, heavily weathered and fractured in upper 1 m, stiff to very stiff, DTPL to 2.3 m APL 2.3 to 7.2 m, WTPL below 7.2 m (Upper Glaciolacustrine Unit)			1	SS	22	19		
				2	SS	22	23		
				3	SS	22	19		
	colour change from greyish brown to grey at 3.4 m			4	SS	18	19		
	several fractures with carbonate infilling at 5.5 m.			5	SS	26	17		
	- silt laminae common over 0.3 m interval at 9.0 m			6	SS	24	19		
				7	SS	17	22		
	- silt laminae common 11.3 to 11.8 m			8	SS	11	29		
				9	SS	14	27		
				10	SS	18	26		
	- increased silt content (17.1 to 17.4 m)			11	SS	18	25		
	- 1 cm thick oblique "seam" of very fine sand at 17.9 m			12	SS	19	22		
20.0	SILTY CLAY TO CLAYEY SILT TILL: brown silty clay to clayey silt, indistinctly laminated, upper and lower contacts gradational, very stiff, WTPL (Halton Till)			13	SS	23	27		
20.4	CLAYEY SILT TO SILTY CLAY: brown silty clay to clayey silt, well laminated with occasional silt laminae (to 1 mm thick), occasional small (<1 cm) pebbles, very stiff to hard, WTPL, very fine sand 21.2 to 21.7 m (Lower Glaciolacustrine Unit)			14	SS	88	19		
				15	SS	21	25		
				16	SS	21	26		

Gartner Lee Associates Limited

BOREHOLE NO. GL 1 (9C) (cont'd)

PROJECT NAME: Phase 4A Drilling and Sampling

CLIENT: Ontario Waste Management Corporation. DATE: September 4, 1984

BOREHOLE TYPE: 108 mm ID Hollow Stem Auger, Continuous Sampling. GEOLOGIST: EJK/AC

GROUND ELEVATION: 185 m (approximately). PROJECT NO.: 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (Wp — Wl) (10 20 30) / COMMENTS
	CLAYEY SILT TO SILTY CLAY (cont'd)			17	SS	20	25		
				18	SS	23	26		
				19	SS	17	36		
				20	SS	19	34		
31.6				21	SS	15	12		
	SILT TILL: brown silt till, sandy to clayey, saturated, very dense (Lower Till)			22	N/A	N/A	N/A		
				23	SS	*	5	* 55/0.2 m (refusal)	
34.8	DOLOSTONE: light grey fine textured dolostone, occasional vugs and shale partings (<0.5 cm thick) (Guelph Formation)								
35.6	Borehole terminated at 35.6 m in dolostone								

BOREHOLE NO. GL-2 (9C)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE August 24, 1985

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 185m (approximately) PROJECT NO. 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0									
0.3	TOPSOIL: very dark greyish brown clayey silt to silty clay topsoil, roots and vegetation			1	SS	19	23		
	SILTY CLAY TO CLAYEY SILT: dark greyish brown to dark grey silty clay to clayey silt, laminated with occasional small (<1 cm) pebble, heavily weathered to ±1 m, occasional fractures with carbonate infilling to 5.5 m, colour change brown to grey at ±4.1 m, Stiff to very stiff, DTPL to 4.1 m, WTPL below 4.1 m, (Upper Glaciolacustrine Unit)			2	SS	25	19		
				3	SS	17	26		
6.5				4	SS	14	16		
	SILTY CLAY TO CLAYEY SILT TILL: dark greyish brown silty clay to clayey silt till, indistinctly laminated, upper and lower boundaries are gradational, stiff, WTPL (Halton Till)			5	SS	11	16		
8.6				6	SS	14	19		
	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, laminated, occasional small (<1 cm) pebble, stiff to very stiff, WTPL (Lower Glaciolacustrine Unit)			7	SS	17	19		
	1 cm lamina of silty fine sand (10.7 m)			8	SS	11	19		
				9	SS	14	19		
				10	SS	15	20		
				11	SS	13	22		
				12	SS	14	20		
	- several inclusions of reddish brown silt till (to 1 cm) 20.5 m			13	SS	9	32		
				14	SS	8	39		
				15	SS	8	34		
				16	SS	10	32		

BOREHOLE NO. GL 2 (9C) (cont'd)

PROJECT NAME: Phase 4A Drilling and Sampling

CLIENT: Ontario Waste Management Corporation — DATE: August 24, 1984

BOREHOLE TYPE: 108 mm ID Hollow Stem Auger, Continuous Sampling — GEOLOGIST: AB/AC

GROUND ELEVATION: 185 m (approximately) — PROJECT NO.: 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) Wp—Wl / COMMENTS
	- occasional silt to very fine sand lamina to maximum 3 mm thickness 26.2 to 29.3 m			17	SS	8	35		
				18	SS	14	37		
29.3				19	SS	10	38		
30.1	SANDY CLAYEY SILT TILL: brown sandy clayey silt till (Lower Till)			20	SS	*	N/A	* 25/0.15 m (refusal)	No sample
31.4	DOLOSTONE: light grey fine textured dolostone with occasional thin (<0.5 cm) shale partings (Guelph Formation)								
	Borehole Terminated at 31.4 m in dolostone								

BOREHOLE NO. GL 3 (9C)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** September 14, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 185m (approximately) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.3	TOPSOIL: dark yellowish brown silt topsoil, minor clay, occasional root.								
	CLAYEY SILT TO SILTY CLAY: dark grey to brown clayey silt to silty clay, well laminated with massive zones, red and grey colour banding, occasional silt laminae (to 1 mm thick), occasional pebble to 1 cm, heavily weathered and fractured in upper ±1 m, stiff to hard, DTPL to 7.2 m, APL 7.2 to 10.7m, WTPL below 10.7 m (Upper Glaciolacustrine Unit)			1	SS	24	21		
				2	SS	23	19		
				3	SS	12	26		
	- occasional gypsum crystal 3.6 to 4.0 m			4	SS	39	14		
	- several fractures with carbonate infilling and gypsum crystals, approximate level of brown/grey colour change 5.7 m			5	SS	34	15		
				6	SS	24	17		
	- fracture with brown discolouration 8.8 to 10.3 m			7	SS	16	17		
				8	SS	18	21		
				9	SS	11	24		
				10	SS	12	25		
16.8									
17.3	SILTY CLAY TO CLAYEY SILT TILL: brown silty clay to clayey silt till, occasional fine laminations, gradational upper and lower contacts, stiff, WTPL (Halton Till)			11	SS	11	25		
				12	SS	11	24		
	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, laminated with red and grey banding, occasional silt lamina to 1 mm thick, occasional pebble to 1 cm, stiff, WTPL (Lower Glaciolacustrine Unit)			13	SS	8	23		
				14	SS	10	31		
				15	SS	9	27		
				16	SS	10	29		

Gartner Lee Associates Limited

BOREHOLE NO. GL 3 (9C) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE September 14,1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger,Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 185 m (approximately) PROJECT NO. 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
	SILTY CLAY TO CLAYEY SILT: (cont'd)			17	SS	12	28		
	- increased pebble content 25.0 to 28.5 m			18	SS	11	26		
				19	SS	9	33		
				20	SS	10	28		
				21	SS	9	34		
32.5	SILT TILL: dark greyish brown silt till, clayey to sandy, 8 cm thick inclusion of medium to coarse sand, dense, saturated (Lower Till)			22	SS	37	9		
33.8	DOLOSTONE: medium grey fine textured dolostone, with shale partings, occasional small (to 2 cm) vug, gypsum in vugs and in fractures (Guelph Formation).								
37.8	Borenole Terminated at 37.8 m in dolostone								

Gartner Lee Associates Limited

BOREHOLE NO. GL 4 (90)

PROJECT NAME: Phase 4A Drilling and Sampling

CLIENT: Ontario Waste Management Corporation — DATE: August 28, 1984

BOREHOLE TYPE: 108 mm ID Hollow Stem Auger, Continuous Sampling — GEOLOGIST: AB/AC

GROUND ELEVATION: 186m (approximately) — PROJECT NO.: 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER
0							
0.2	TOPOSIL: black silt topsoil, organic, occasional root.						
	SILTY CLAY TO CLAYEY SILT: dark grey to dark greyish brown silty clay to clayey silt, laminated, occasional silt lamina to 1 mm, occasional pebble to 1 cm heavily weathered and fractured to ±1 m, numerous fractures to 2.7 m, colour change brown to grey at ±5.7 m, firm to very stiff, DTPL to 1.5 m, APL 1.5 to 3.1 m, WTPL below 3.1 m (Upper Glaciolacustrine Unit)			1	SS	16	24
				2	SS	11	23
				3	SS	7	30
6.8				4	SS	5	22
	SILTY CLAY TO CLAYEY SILT TILL: brown silty clay to clayey silt till, occasional red shale pebble, indistinctly laminated, gradational upper and lower contacts, stiff, WTPL (Halton Till)			5	SS	11	20
10.4				6	SS	12	13
	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, laminated with occasional silt lamina to 1 mm thick, silt laminae common 12.0-13.0 m and 21.0 to 24.0 m (no silt laminae 24.0 to 30.0 m), occasional pebble to 1 cm, stiff, WTPL (Lower Glaciolacustrine Unit)			7	SS	13	21
				8	SS	15	21
				9	SS	10	21
				10	SS	14	23
				11	SS	9	26
				12	SS	11	30
				13	SS	12	26
				14	SS	8	29
				15	SS	10	30
25				16	SS	14	30

PENETRATION RESISTANCE BLOWS/0.3m: 20 40 60

WATER CONTENT % / COMMENTS: 10 20 30 — Wp — Wl

Gartner Lee Associates Limited

BOREHOLE NO. GL 4 (9C) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE August 28, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 186 m (approximately) PROJECT NO. 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) Wp — Wl	COMMENTS
	SILTY CLAY TO CLAYEY SILT: (cont'd)			17	SS	12	28			
				18	SS	13	26			
				19	SS	10	36			
				20	SS	9	37			
31.1										
	SILT TILL: dark grey brown silt till, clayey to sandy, saturated, very dense (Lower Till)			21	SS	69	7			
				22	SS	79	7			
34.4										
35.5	DOLOSTONE: finely banded light grey fine-grained dolostone, occasional small (<1 cm) vugs, occasional shale interbed. (Guelph Formation)									
	Borehole Terminated at 35.5 m in dolostone									

BOREHOLE NO. GL 5 (9C)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE August 28, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling GEOLOGIST EJK/AC

GROUND ELEVATION 184m (approximately) PROJECT NO. 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0									
0.3	TOPSOIL: very dark grey silty clay topsoil, organic rich, numerous roots								
	CLAYEY SILT TO SILTY CLAY: dark grey to brown clayey silt to silty clay, well laminated with massive zones, red and grey laminations, occasional silt lamina to 1 mm, occasional small (<1 cm) pebble dominantly silt 1.9 to 3.6 m and 4.1 to 4.4 m, colour change brown to grey at ±5.2 m, upper ±1 m heavily weathered and fractured, fractures to 3.3 m, firm to very stiff, APL to 3.6 m, WTPL below 3.6 m (Upper Glaciolacustrine Unit)			1	SS	23	25		
				2	SS	20	23		
				3	SS	16	22		
				4	SS	5	33		
7.6				5	SS	7	20		
	SILTY CLAY TO CLAYEY SILT TILL: brown silty clay to clayey silt, laminated, gradational upper and lower contacts, firm to stiff, WTPL (Halton Till)			6	SS	8	20		
9.6									
	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, laminated with occasional silt lamina to 1 mm thick, red and grey colour banding, occasional small (<1 cm) pebble, silt dominant 10.2 m, stiff to very stiff, WTPL (Lower Glaciolacustrine Unit)			7	SS	11	19		
				8	SS	12	25		
				9	SS	8	25		
				10	SS	9	22		
				11	SS	9	22		
	- 1 cm thick lamina grey silty fine sand			12	SS	18	23		
				13	SS	17	26		
				14	SS	6	27		
				15	SS	11	32		
25				16	SS	11	29		

Gartner Lee Associates Limited

BOREHOLE NO. GL 5 (9C) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE August 28, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continous Sampling GEOLOGIST EJK/AC

GROUND ELEVATION 184 m (approximately) PROJECT NO. 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (WP — WL) / COMMENTS (10 20 30)
	SILTY CLAY TO CLAYEY SILT: (cont'd)			17	SS	10	26		
				18	SS	17	32		
				19	SS	11	29		
				20	SS	13	30		
32.3				21	SS	11	32		
33.0	SANDY SILT TILL: brown sandy silt till, saturated, 24 cm thick inclusion of silty medium sand, compact (Lower Till)			22	SS	17	9		
34.6	DOLOSTONE: grey fine grained dolostone with shale partings and small (<1 cm) vugs (Guelph Formation)								
	Borehole terminated at 34.6 m in dolostone								

8.6 SUPPORTING CALCULATIONS AND METHODS

In 1856, the French hydraulics engineer Henry Darcy reported that flow through a porous medium is proportional to the head loss and inversely proportional to the distance travelled. The formulation of these relationships is called Darcy's Law and may be written as specific discharge (v) = hydraulic conductivity (K) x gradient (i). The specific discharge is the total discharge per unit area of the discharging porous medium and does not indicate the velocity of the water 'particles'. The velocity of the water (average linear velocity, $\bar{v}$) may be obtained by dividing the specific discharge (v) by the effective porosity (n) of the porous medium. Because effective porosity is always less than 1, the averge linear velocity ($\bar{v}$) is always greater than the specific discharge (v).

$$\text{Average Linear Velocity } (\bar{v}) = \frac{\text{hydraulic conductivity (K) x gradient (i)}}{\text{effective porosity (n)}}$$

Lateral Ground Water Flow

Once the above parameters are known for a porous medium, an average linear velocity may be calculated. The following example utilizes values typical of lateral flow in the fractured zone:

- hydraulic conductivity (K) 1×10^{-8} m/s
- lateral gradient (i) 0.003
- effective fracture porosity 0.0001

$$\bar{v} = \frac{Ki}{n} = \frac{1 \times 10^{-8} \times 0.003}{0.0001} = 3 \times 10^{-7} \text{ m/s or } \approx 9.5 \text{ m/year.}$$

Vertical Ground Water Flow

The application of Darcy's Law to ground water flow through layered porous media when the layers have differing thicknesses and hydraulic properties is discussed in Freeze and Cherry (1979) and is summarized below with regard to the area under study. The layered porous media of interest are the confining layer subunits which usually include the fractured zone; the unfractured zone and the lower till. Estimating the rates of ground water flow in each of these layers involves (1) the calculation of a single equivalent hydraulic conductivity for the three layers, (2) calculation of the specific discharge through the layers and (3) the calculation of average linear velocities in each of the layers.

The calculation of an equivalent hydraulic conductivity (Ke) for the three-layer situation is:

$$Ke = \frac{d(FCL + CL + LT)}{\frac{dFCL}{KFCL} + \frac{dCL}{KCL} + \frac{dLT}{KLT}}$$

where K and d are the hydraulic conductivity and thickness respectively and the subscripts are 'e' (equivalent), 'FCL' (fractured confining layer), 'CL' (confining layer) and 'LT' (lower till).

The calculation of specific discharge (v) uses the equivalent hydraulic conductivity (Ke) and the overall vertical gradient (i) across the layers in Darcy's Law:

$$v = Ki$$

And finally, the average linear ground water velocity ($\bar{v}$) in each layer is obtained by dividing the specific discharge (v) by the effective porosity (n) for each of the layers involved.

The following example uses numbers similar to those in the report (values relate to the layers identified above; thicknesses are in m and hydraulic conductivities are in m/s).

$$Ke = \frac{34.8}{\frac{5.0}{1\times10^{-8}} + \frac{26.6}{3\times10^{-10}} + \frac{3.2}{1\times10^{-8}}} = \frac{34.8}{9.0\times10^{+10}} = 3.9\times10^{-10} \text{ m/s}$$

where the vertical gradient (i) is 0.3:

$v = Kei = 3.9\times10^{-10} \times 0.3 = 1.2 \times 10^{-10}$ m/s

or 3.7×10^{-3} m/year.

The average linear velocity ($\bar{v}$) = specific discharge divided by the effective porosity for each individual layer.

For the fractured confining layer, effective porosity (n) = 0.0001 and the average linear velocity ($\bar{v}$) =

$1.2 \times 10^{-10}/0.0001 = 1.2 \times 10^{-6}$ m/s or $\sim$3.8 m/year.

For the unfractured confining layer, no effective porosity value is available and consequently a total porosity value of 0.5 is used to calculate an average linear velocity ($\bar{v}$):

$$\bar{v} = 1.2 \times 10^{-10} / 0.5 = 2.3 \times 10^{-10} \text{ m/s}$$
$$7.3 \times 10^{-3} \text{ m/year.}$$

For the lower till, no effective porosity value is available, and consequently a total porosity value of 0.3 is used to calculate an average linear velocity:

$$1.2 \times 10^{-10} / 0.3 = 3.9 \times 10^{-10} \text{ m/s}$$
$$\text{or } 1.2 \times 10^{-2} \text{ m/year.}$$

(These are approximate values and are usually rounded to one significant figure in the text).

The major assumptions for these calculations are:

(1) steady state estimated flow
(2) flow in a direction perpendicular to the layering
(3) layers are homogeneous and isotropic, and
(4) flow is governed by Darcy's Law. A more complete and theoretical discussion is given in Freeze and Cherry (1979).

For a more accurate discussion of ground water flow rates through the confining layer based on advection and diffusion calculations, the reader is referred to Appendix A of the report entitled "Site Selection Process; Phase 4A, Selection of Preferred Site(s), Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

8.7 GLOSSARY OF SELECTED TERMS

Sources are provided at the rear of this section and are referenced by the bracketed number following each definition.

Some definitions are altered slightly to reflect useage in this report and may not reflect the wide range of meanings provided in the source.

8.7 GLOSSARY OF SELECTED TERMS

Alluvium
Sediment composed of organic material, clay, silt, sand, gravel cobbles, or boulders deposited by postglacial streams. (2)

Aquifer
A body of sediment (or rock) that contains sufficient saturated permeable material to conduct ground water and yield economically significant quantities of ground water to wells and springs.(2)

Bearing Pressure (Allowable)
Means the maximum pressure that may be safely applied to a soil or rock by the foundation unit in design under expected loading and subsurface conditions. (8)

Confining Bed (Layer)
A body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers. (1)

Darcy's Law
For the velocity of percolation of water in saturated soil: Velocity = coefficient of permeability x hydraulic gradient. (4) (hydraulic conductivity is used in place of coefficient of permeability in this report).

Desiccated Crust
The exposure of fine-grained sediments to drying is accompanied by shrinkage and possibly cracking. Precompression of the upper portions of clay layers by drying is frequently observed in many of the profiles encountered in practice. The effects of desiccation are an increase in strength and a decreased water content. (6)

Drawdown
The lowering of the water level in a well as a result of withdrawal. (1)

Drift
A general term applied to all rock material (clay, silt, sand, gravel, boulders) transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier. (1)

Evaporite
A nonclastic sedimentary rock composed primarily of minerals produced from a saline solution as a result of extensive or total evaporation of the solvent. Examples include: gypsum, anhydrite, rock salt, primary dolomite, and various nitrates and borates. (3)

Geometric Mean
The nth root of the product of the values of n positive numbers; the antilogarithm of the mean of the logarithms of individual values. (1)

Geotechnical, Geotechnics
Pertaining to the broad field of geotechnics. The application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust for the solution of engineering problems. (1)

Glacial Lake
A lake fed predominantly by glacial meltwater or a lake in a depression in part closed by glacial ice. Includes lakes not directly adjacent to the glacier and lakes lying against or on a glacier, and fed mainly by waters derived from the melting of a glacier. (2)

Glaciofluvial
Pertaining to streams flowing from glaciers or to the deposits made by the streams. (2)

Glaciolacustrine
Pertaining to or characterized by glacial and lacustrine (lake) conditions. Material deposited in lakes affected by glacier ice, or deposited by meltwater flowing directly from glaciers into a lake. (2)

Ground Water
Subsurface water occurring below the water table (phreatic surface) in the saturated zone in which all pores are filled with water under hydrostatic pressure. This contrasts with subsurface water above the water table, which is referred to as soil moisture. (2)

Grout
A cement slurry of high water content, fluid enough to be poured or injected into spaces and thereby fill or seal them. (1)

Hardness (Water)
A property of water causing formation of an insoluble residue when the water is used with soap, and forming a scale in vessels in which water has been allowed to evaporate. It is primarily due to the presence of ions of calcium and magnesium, but also to ions of other alkali metals, other metals (e.g. iron), and even hydrogen. Hardness of water is generally expressed as parts per million as $CaCO_3$ (40 ppm Ca produces a hardness of 100 ppm as $CaCO_3$); also as milligrams per litre, and is the combination of carbonate hardness and noncarbonate hardness. (1)

Hazardous Waste
Waste that poses a present or potential danger to human beings or other organisms because it is toxic, flammable, radioactive, explosive, or has some other property that produces substantial risk to life. (1) (Use here excludes radioactive waste)

Heave
A predominantly upward movement of a surface, caused by expansion or displacement, as from swelling clay, removal of overburden, seepage pressure, or frost action. (1)

Hydraulic Gradient
In an aquifer, the rate of change of total head per unit of distance of flow at a given point and in a given direction. (1)

Hydraulic Head
The height of the free surface of a body of water above a given subsurface point. (1)

Hydraulic conductivity
The proportionality factor in Darcy's law as applied to the viscous flow of water in soil, that is, the flux of water per unit gradient of hydraulic potential. (3)

Hydrogeology
The science that deals with subsurface waters and with related geologic aspects of surface waters. (1)

Hydrostratigraphic Unit
A term proposed by Maxey (1964, p. 126) for a body of rock having considerable lateral extent and composing "a geologic framework for a reasonably distinct hydrologic system". (1) (used here for soil and rock).

Infiltration
The flow of a fluid into a solid substance through pores or small openings; specifically the movement of water into soil or porous rock. (1)

Lamina
The thinnest recognizable unit layer of original deposition in a sediment or sedimentary rock, differing from other layers in colour, composition, or particle size; specifically such a sedimentary layer less than 1 cm in thickness (commonly 0.05-1.00 mm thick). (1)

Log
A continuous record as a function of depth, usually graphic and plotted to scale on a narrow paper strip, of observations made on the rocks and fluids of the geologic section exposed in a well bore. (1) (used here for soil and rock).

Moraine
Accumulation of glacial material (mainly till) deposited by glaciers. (2)

Particle Size Classification System (9)

Name	Qualifying Term	Approximate Particle Size (mm)
Boulders		>200
Cobbles		60-200
Gravel	(Pebble)	2-60
Sand	Coarse	0.6-2
	Medium	0.2-0.6
	Fine	0.06-0.2
Silt		0.002-0.06
Clay		<0.002

Permeability
The capacity of a porous medium to transmit a liquid or gas subjected to an energy gradient (in the case of water, hydraulic gradient). (2)

Porosity
The ratio of the volume of voids to the total volume of a soil sample. (4). Effective porosity is the amount of interconnected space available for fluid transmission (3).

Quaternary
The youngest period of the two geologic time divisions of the Cenozoic Era. The Quaternary is subdivided into the Pleistocene and Recent (or Holocene) Epochs. It comprises all geologic time and deposits from the end of the Tertiary (approximately 2 million years ago) until and including the present. (2)

Saturated
Said of the condition in which the interstices of a material are filled with a liquid, usually water. It applies whether the liquid is under greater than or less than atmospheric pressure, so long as all connected interstices are full. (1)

Settlement
Downward movement of a structure such as a railway bridge, dam, or building, due to compression or movement of the soil below it. (4)

Shear Strength
The internal resistance offered to shear stress. It is measured by the maximum shear stress, based on original area of cross-section, that can be sustained without failure. (5)

Two extreme conditions may be recognized: drained conditions, under which the changes in stress are applied so slowly with respect to the ability of the soil to drain that no excess pore pressures develop, and undrained conditions, under which the stresses are changed so rapidly with respect to the ability of the soil to drain that no dissipation of pore pressure takes place. (7)

Slug Test
A method of determining in situ hydraulic conductivity in a single piezometer by causing an instantaneous change in the water level by adding or displacing a known volume of water. (10)

Split Spoon Sampler
Sampling spoons for exploratory borings commonly consist of a pipe with an inside diameter of about 35 mm and an outside diameter of about 51 mm. The pipe is split lengthwise. Consequently the sampler is called a split spoon. While the sample is being taken, the two halves of the spoon are held togther at the ends by short pieces of threaded pipe. One piece serves to couple the spoon to the wash pipe. The other, which has been sharpened, serves as the cutting edge while the spoon is driven into the soil. Exact dimensions are designated in ASTM DI586-67. (7)

Static (Water) Level
That water level of a well that is not being affected by withdrawal of ground water. (1)

Stratigraphic Unit
A stratum or body of adjacent strata recognized as a unit in the classification of a rock sequence with respect to any of the many characters, properties, or attributes that rocks may possess. (1)

Surcharge Load
A weight per unit of area of fill great enough to consolidate the soil sufficiently to increase its strength or reduce its compressibility to the required extent within the time available. Compressible soils such as clays, loose silts, and most organic soils may be compacted by surcharging. (7)

Till
An unsorted mixture of clay, silt, sand, pebbles, cobbles and boulders deposited directly by glacier ice. (2)

Water Table
A surface in the saturated zone below ground level along which the hydrostatic pressure is in equilibrium with the atmospheric pressure. (2)

Weathering
The destructive process or group of processes by which earthy and rocky materials on exposure to atmospheric agents at or near the earth's surface are changed in colour, texture, composition, firmness, or form with little or no transport of the loosened or altered material; specifically, the physical desintegration and chemical decomposition of rock that produce an in situ mantle of waste and prepare sediments for transportion. (1)

SOURCES

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8.8 DETAILED FIELD METHODS

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8.8.1 INTRODUCTION

Field data for of the Phase 4A hydrogeologic onsite investigations were collected in a standardized fashion and formed part of the basis for geologic, hydrogeologic, and geotechnical comparisons of the eight candidate sites. An outline of the major field activities is shown in Figure 9. The study approach was modified only slightly on a site-by-site basis to accommodate differing circumstances and site conditions. Standard procedures for the drilling and sampling operations, as outlined in the Gartner Lee Associates Ltd. "Drilling and Sampling Protocol" document (GLAL 1984a), were adhered to throughout the drilling program. This protocol document provides examples of field forms used to document field activities and should be referred to for more detailed drilling and sampling procedural descriptions.

8.8.2 DRILL SITE IDENTIFICATION

8.8.2.1 Preliminary data analysis

A preliminary review of existing water well and test hole data was completed to establish a basis for the selection of tentative drill locations. Criteria used included the following:

- the distribution of existing test holes and water wells;
- the continuity of existing data; and
- anomalous or unusual site conditions.

While locations were selected primarily on technical grounds, practical considerations such as site access, potential crop damage, and landownership were also taken into account.

DETAILED FIELD METHODS

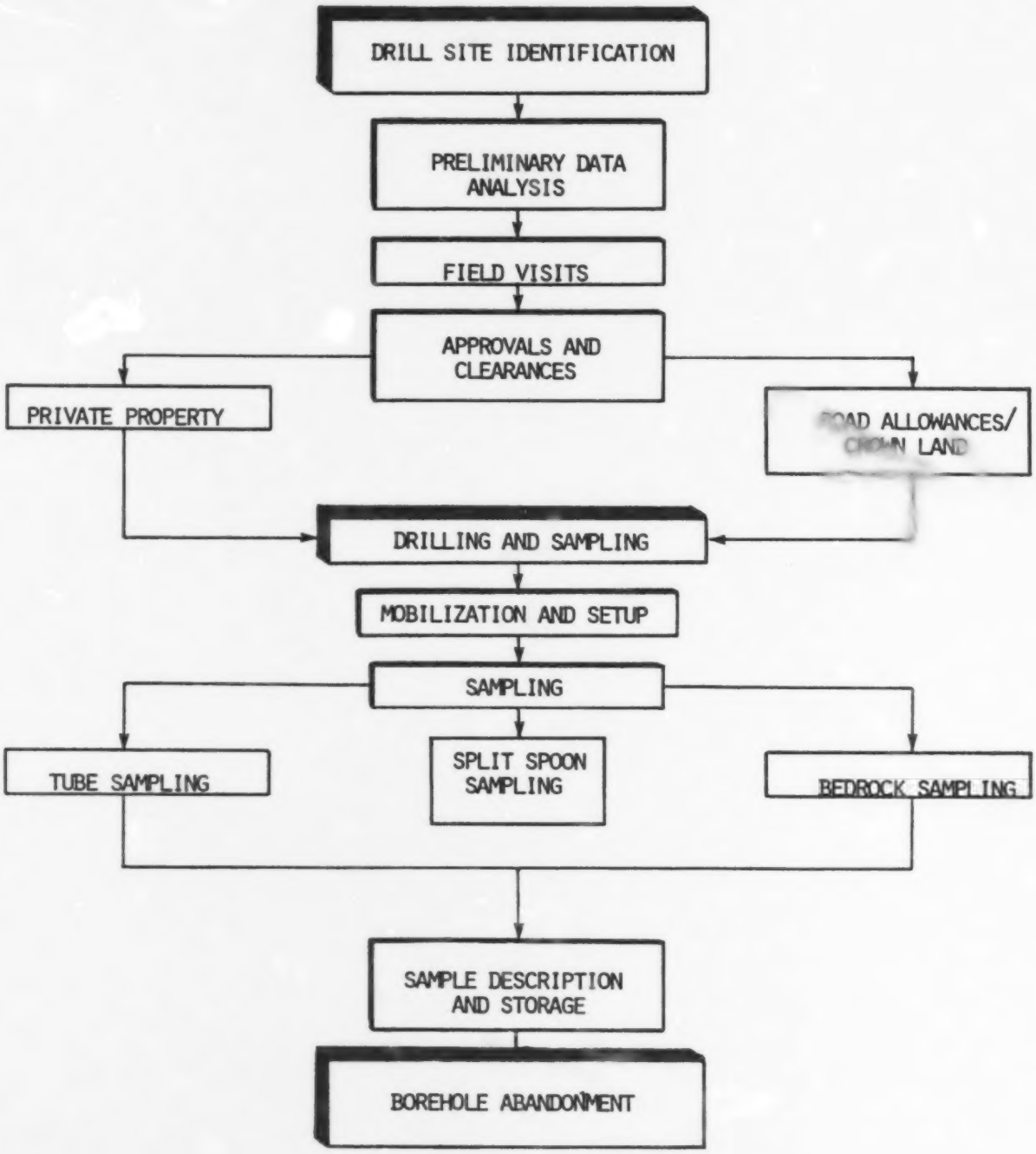


Figure 9

8.8.2.2 Field visits

The concerns of local public interest groups and individuals were also considered in selecting drill locations. Local interest groups were invited to participate during field checking of the drill locations. During these field visits, additional data on water use, local soil conditions, and wells were obtained from local residents. This information was used as a check on some of the field data obtained previously by Ecolgistics Limited during the 1984 "Walk and Talk" survey. The amount of information thus obtained varied from site-to-site and depended largely upon the degree of co-operation given by residents and landowners.

A limited amount of soil probing was completed at Candidate Sites LF-3C, LF-9C, and PI-13N using a 25 mm (1 inch) magnesium hand auger. These investigations were generally limited to a depth of 1 to 2 m. Hand augering was directed toward areas of suspected granular soils or anomalous soil conditions identified by local residents. Soil probing was confined to areas where property access was permitted. Soil descriptions are included under "Field Station Descriptions" in the individual technical site reports.

The tentative drill locations were adjusted during the field visits to avoid difficult or unsafe drilling locations. Each location was marked with a temporary wooden stake. Final adjustments were subsequently made, where necessary, to provide the required safe setbacks from buried and overhead services.

8.8.2.3 Approvals and Clearances

Clearances for both road allowances and adjacent private

or public property were pursued where identified drilling locations were located in the vicinity of local roads. Road allowances were drilled where access to private property was denied.

Landowners and tenants of affected properties were initially contacted by GLAL and verbal approval for test drilling was obtained. Approval was confirmed with a follow up letter from OWMC. For road allowance clearances, the appropriate agencies were contacted and the necessary permit approvals were obtained.

Utilities were contacted and buried service cables and/or pipes were field located by utility personnel and final adjustments of drill locations were completed. Drilling approvals and clearances were completed on a site-by-site basis.

8.8.3 DRILLING AND SAMPLING

8.8.3.1 Drilling equipment and setup

All Terrain Drilling Limited was retained to provide drilling services. The drilling equipment included truck and track mounted CME 75 auger drilling rigs. Two rigs were used simultaneously for most of the drilling program. Each rig was equipped to drill and sample both soils and bedrock. Each rig was staffed with a three man drilling crew and supervised by a GLAL geologist. The drilling program was initiated on August 13, 1984 at Site LF-3C and was completed on November 22, 1984 at Site LF-4N.

The drill rigs were set up in accordance with standard drilling practices and in a manner that allowed the safe

and efficient operation of the equipment. A safety corridor was roped-off around the drill rig to limit access to the rigs. Access to the roped-off area was restricted to individuals with proper safety equipment which included steel-toed boots and a hard hat. A record was kept of all visitors to the drill site as well as persons entering the roped-off area.

Sample documentation and storage facilities were set up at the edge of the roped-off area by GLAL. Soil and rock samples were accessible to the general public for viewing and/or photographing as the samples were being logged by the onsite geologists. Samples were subsequently sealed in tubes or core boxes, labelled, and placed in storage. On several occasions, soil sample tubes were re-opened for examination at the request of local residents.

8.8.3.2 Soil sampling

The drilling program was designed to obtain a continuous column of soil from the ground surface to and including the upper few metres of the underlying bedrock. Soil samples were obtained using hollow stem auger drilling techniques. Hollow stem augers (108 mm (4.25 inch) inside diameter) were used throughout the drilling program.

Split tube sampling. Tube samples measuring approximately 89 mm (3.5 inches) in diameter by 1.52 m (5 ft.) in length were taken continuously from ground level to the bedrock surface. The tube sampler consisted of a split tube with a bevelled sampler tip. The split tube was threaded at both ends and fastened to the drill rods as shown in Figure 10. The sampler as advanced inside the hollow stem augers with

Continuous Soil Sampling With Split Tube Sampler

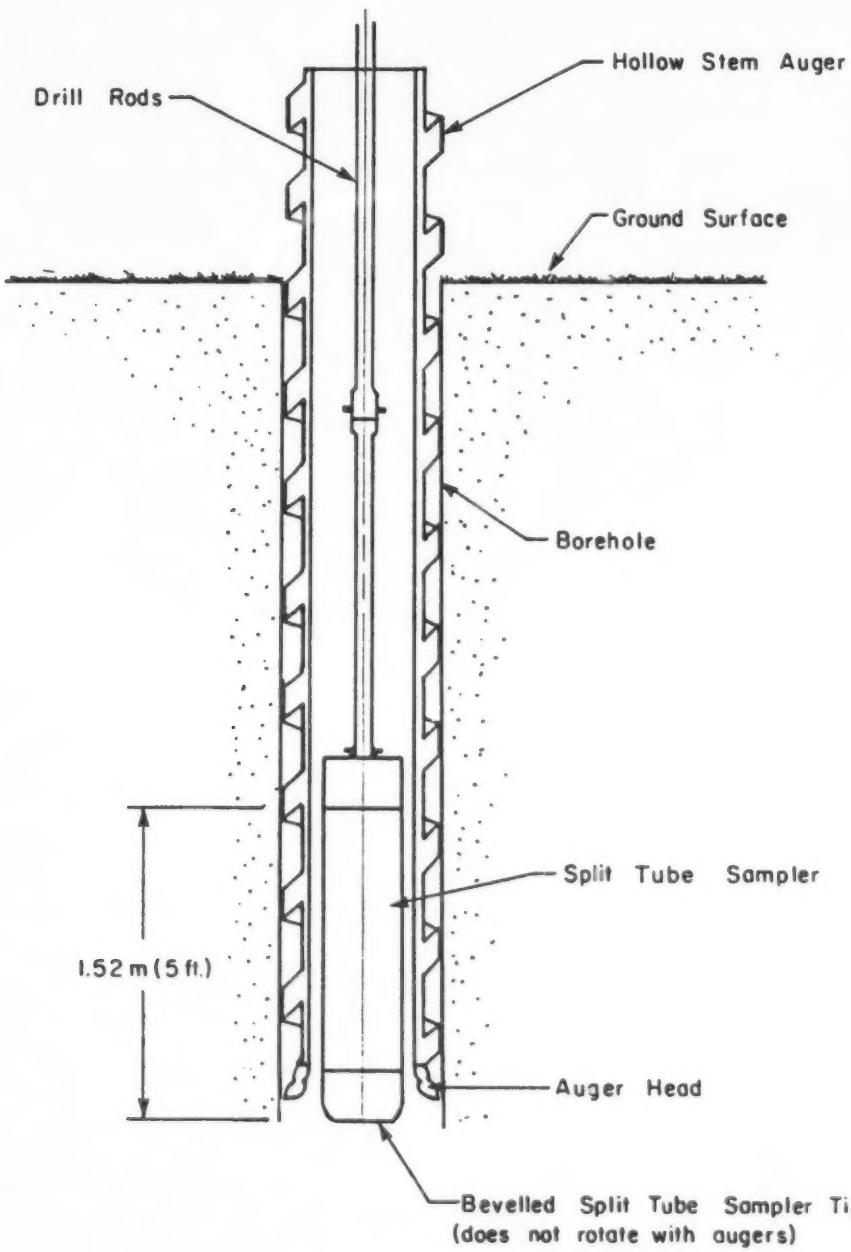


Figure 10

the bevelled tip slightly ahead of the cutting edge of the augers. A split tube sample was obtained by advancing the sampler with the rotating augers. The augers and sampler were advanced at about 1.52 m (5 ft.) intervals or until refusal, and the sampler was then withdrawn from the borehole. The soil sample was removed from the tube and the sampler washed with clean water. Sample recovery for the tube samples was generally between 90 to 100% and was recorded in the field log. Difficult drilling conditions or large cobbles occasionally resulted in lower sample recovery.

Split spoon sampling. Standard split spoon samples were taken at about 1.52 m (5 ft.) intervals throughout the soil sequence overlying bedrock and beginning at about 1.52 m 5 ft.) from the ground surface. Sample intervals are shown schematically in Figure 11.

The split spoon sampler was driven by dropping a 63.5 kg (140 lb.) weight a distance of about 750 mm (30 inches). The sampler was inserted inside the hollow stem augers in a similar fashion to the tube sampler. It was then driven into the soil below the bottom of the augers a distance of about 460 mm (18 inches) or until refusal. The number of blows required to advance the sample for each interval of about 150 mm (6 inches) was recorded in the field log. The split spoon was usually withdrawn when 50 or more blows were required to advance the sampler approximately 150 mm (6 inches) into the subsoil.

Standard split spoon samples were obtained in place of tube samples where difficult drilling conditions were

Soil & Rock Sample Intervals Phase 4A Drilling Program

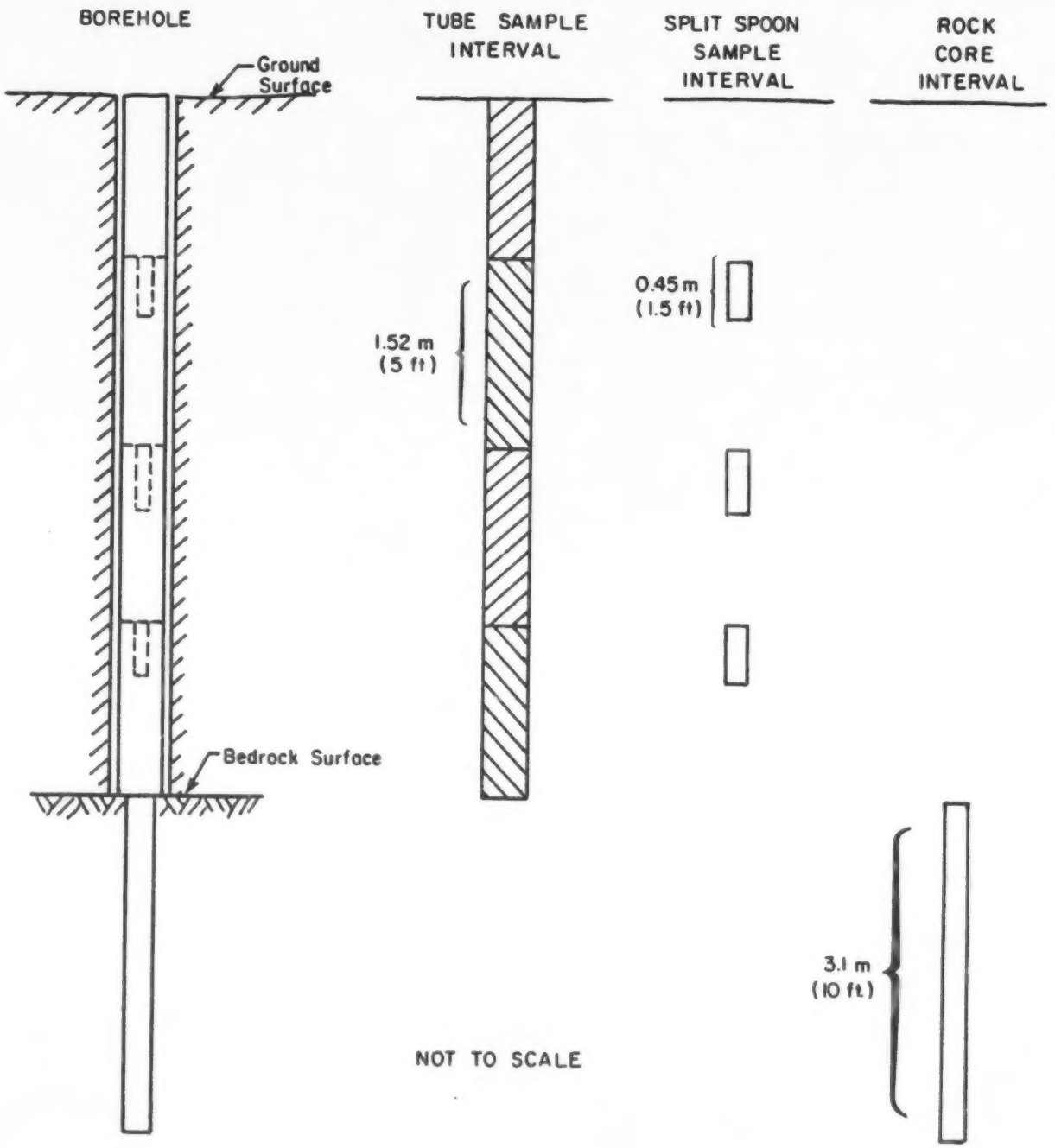


Figure 11

encountered. At Site LF-4N, Borehole 4, granular soils were encountered at a depth of about 30 m (100 ft.) causing refusal of the tube sampler. Standard split spoon samples were taken from a depth of 30 m (100 ft.) at intervals of 0.5 to 3 m (1.6 to 9.8 ft.) to a depth of about 40 m (130 ft.). Difficult soil conditions were also encountered at Site LF-2N, Borehole 1. Numerous rock fragments were encountered below a depth of about 12 m (40 ft.) at this location. Split spoon samples at 0.76 m (2.5 ft.) intervals were taken between depths of about 12 m (40 ft.) to 34 m (110 ft.).

Difficult (sandy and gravelly) soil conditions at Site PI-27E, Borehole 3 prevented tube sampling between depths of about 16 to 30 m (50 to 100 ft.). Similar fine, sandy soils were also encountered in Borehole 4 at this site at depths between approximately 24 to 30 m (80 to 100 ft.). Standard split spoon samples at 1.5 m (5 ft.) intervals were collected over these intervals at these two borehole locations.

Moisture tin samples. A small soil sample of approximately 100 grams was taken from the tip of each split spoon sample for laboratory determination of the soil moisture content. Soil moisture samples were placed in air tight tins immediately after they were taken from the split spoon samples. The moisture tin (sample) numbers were recorded on the field borehole logs. The samples were temporarily stored in the field and shipped in batches to the GLAL office for transfer to a commercial laboratory.

Rotary drilling. Rotary drilling techniques were occas-

ionally used to penetrate difficult soils that could not readily be drilled with conventional hollow stem auger drilling methods. These techniques were also used where granular soils, acting under hydraulic pressures, were forced up inside the hollow stem augers. This condition prevented the split tube and split spoon samplers from passing through the plugged portions of the hollow stem augers. Clean water or a water/bentonite mixture was circulated through a rotating tricone drill bit to clean out the material in the hollow stem augers. Rotary drilling was also used to drill through gravelly or bouldery soils such as those encountered at depth at Site LF-4N, Borehole 4, and at Site LF-2N, Borehole 1.

8.8.3.3 Bedrock sampling

Boreholes were generally completed into bedrock except in a few cases where difficult drilling conditions were encountered and the borehole was terminated before reaching bedrock.

The bedrock contact was often obscured as a result of weathering, particularly in shale. Under conditions of extreme weathering, shale was occasionally retrieved within the split tube and split spoon samplers. For example, a nearly complete 1.5 m core of weathered bedrock was obtained in the split tube sampler in Borehole 5 at Site PI-13N.

Diamond drill coring. Most bedrock samples were obtained using a diamond drill bit and NX size core barrel. Rock core samples generally measured about 53 mm (2.1 inches) in diameter and up to 3 m (10 ft.) in length. The diamond drill bit and core barrel were positioned on the bedrock

surface from inside the hollow stem augers. A rock core was obtained by the cutting action of the rotating drill bit. Clean water was circulated in the borehole to remove cuttings from around the drill bit. The water used in this operation was field checked with a Hach Kit for chlorides and sulphates to ensure compatibility with grouting materials used for borehole abandonment. The amount of water used was recorded on the field logs.

Bedrock coring was terminated when a sufficient length of sample was retrieved to prove-out the bedrock contact. The bedrock core recovered varied in length from about 1.5 m to 3 m (5-10 ft.) between borehole locations.

8.8.3.4 Sample description and storage

Soil and rock samples, taken from the boreholes, were described in detail in the field and photographed. Sample descriptions were recorded on the Field Borehole Log forms. These logs, together with the sample photos, form a permanent record of the sampling procedures.

The tube samples were transferred directly from the sampler into PVC tubular piping which was cut in half. The PVC pipe measures 89 mm (3.5 in.) inside diameter by 1.5 m (5 ft.) long. One 'side' of the sample was scraped clean along its length with a knife or spatula to facilitate sample description. Individuals and local interest groups were allowed to view the samples and make their own field notes of the samples. Soil scrapings were given to those interest groups that requested them or else were discarded. Soil samples were sealed in the PVC tubes by covering the

ends with plastic caps and taping the entire tube along the seams. Sample labels were affixed to each PVC tube.

The samples were stored temporarily in a field van until a sufficient number of samples were obtained for transport to permanent storage facilities in Toronto at the Ontario Geological Survey. Each shipment of samples were itemized on a Sample Packing list. The contents of each shipment were also recorded on a Chain of Custody Record which showed the times and dates of sample transfer as well as the individuals involved in handling the samples.

Split spoon soil samples taken during the project were described in the field and soil moisture (moisture tin) samples taken from the base of the split spoon sampler were submitted to a laboratory for analysis. The moisture tin number was recorded on the Field Borehole Log and on the Sample Packing List. In cases where a split spoon sample was taken in place of the larger split tube samples, they were stored in labelled plastic bags and retained with the other samples. The top of each bedrock core segment was marked on both the core boxes and on the rock core itself with a felt marker.

The soil and rock samples were re-examined by a senior GLAL geologist at the permanent storage area at the Ontario Geological Survey. The field descriptions were combined with the more detailed geologic log prepared by the senior geologist to compile a final borehole log. All soil samples were resealed after examination.

8.8.4 BOREHOLE ABANDONMENT

Boreholes were generally terminated after pentrating the bedrock or when difficult conditions prevented further drilling. An exception to this occurred at Site LF-1E, Borehole 3, where a gas pocket was encountered at a depth of about 17.8 m (58 ft.) in the drift. The borehole was terminated at this depth and sealed as soon as the gas pressure subsided sufficiently to allow grouting.

8.8.4.1 Grouting

On completion of each borehole all sampling equipment and temporary casing were removed from the borehole. Each borehole was then filled to the surface with a cement/ bentonite slurry. This was accomplished by injecting grout through the hollow stem augers as they were slowly withdrawn from the hole as shown in Figure 12. Specifications of the slurry mix, as set out in the Drilling and Sampling Protocol Document (GLAL 1984a) were altered slightly to accommodate site conditions. The actual grout slurry mix is compared on a percent weight basis to the specified grout slurry mix below:

Specified Grout Slurry	Actual Grout Slurry
1.2% Bentonite	2-3% Bentonite
6.0% Hydrated Lime (optional)	
59.6% Cement	40-60% Cement
(Portland Type 10)	(Portland Type 10)
33.2% Water	37-58% Water

The increased amount of bentonite provides a more effective seal in water bearing formations. The bentonite also acts as a 'plasticizing' agent and eliminated the need

Grouting Of Borehole

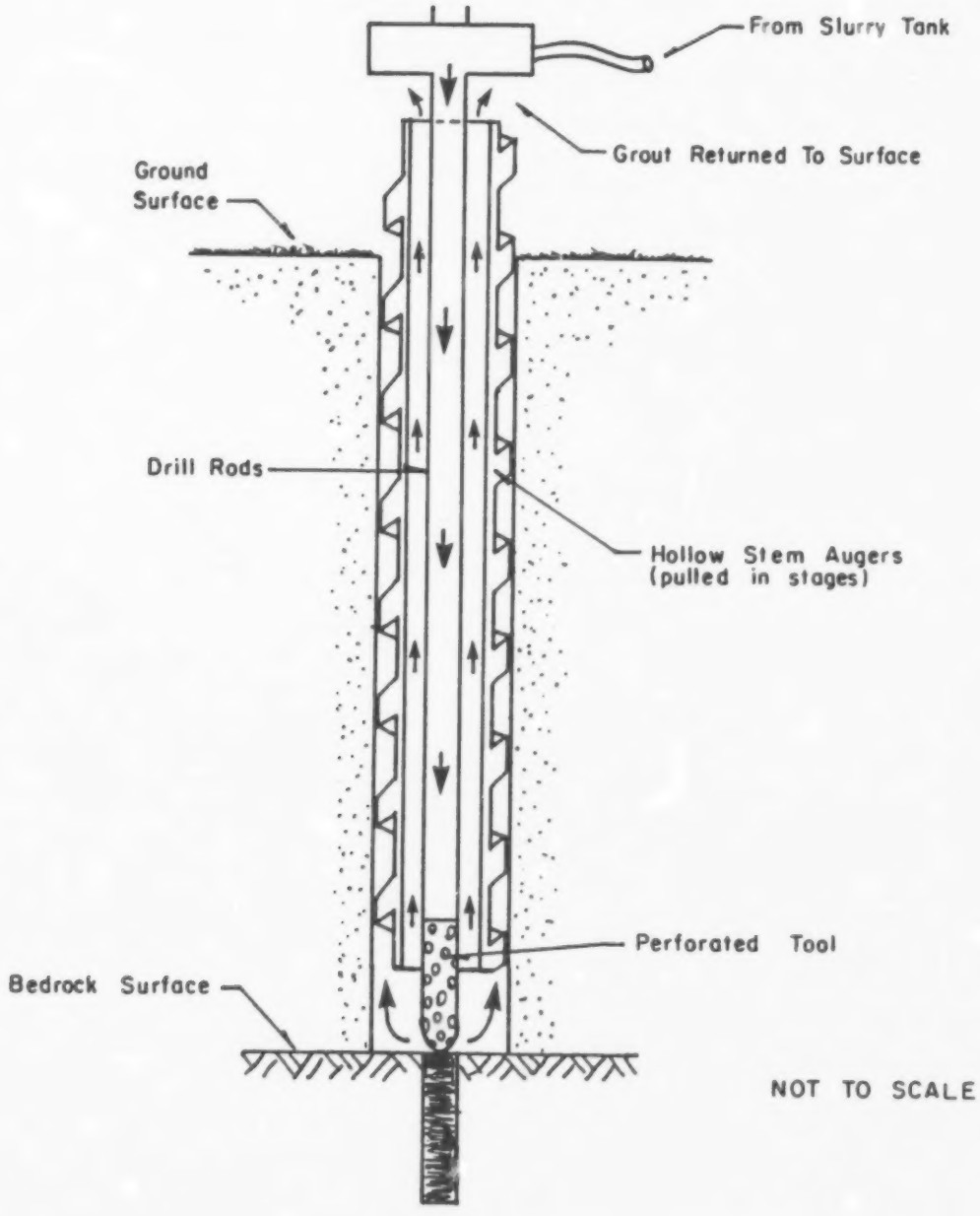


Figure 12

to add hydrated lime to the grout slurry mix. A cement mix containing slightly less than the amount of cement specified in the protocol was found to be adequate. A small sample of grout slurry was taken from each hole to confirm the setting characteristics of the mix.

The water used in the grout slurry was obtained locally and was tested wth a Hach Kit for sulphate and chloride content. Details of each grout mix were recorded on the Borehole Plugging Plan/Record for each borehole.

The grout was allowed to set overnight and generally settled to within 1 to 3 m (3-10 ft.) of ground surface. The hole was subsequently backfilled to grade with soil to avoid interference with surface activities such as ploughing or maintenance along road allowances. All boreholes from this drilling program were successfully grouted.

8.8.4.2 Site cleanup

Efforts were made to restore each drill location to predrilling conditions. The ground was levelled to grade and holes or ruts made by drilling equipment were filled with soil and in some cases resodded. While attempts were made to minimize damage, this was not always possible and compensation was provided in some cases. Photographs were taken of each drill location both before and after the drilling operations and after site cleanup.

LOT 17 CON 5

BOYD ROAD

SILVERDALE ROAD

JACKINS ROAD

CROWN ROAD

LOT 4 CON 5

ROSEDENE

CONCESSION ROAD 4

LOT 17 CON 4

LOT 25 CON 4

B

1947(187)

2164(187)

469(184)

LOT 17 CON 3

SCHRAM ROAD

GL4(186)

GL3(185)

GL5(184)

447(183)

VAUGHAN ROAD

LOT 24 CON 2

BOYLE ROAD

LOT 18 CON 2

A

468(185)

467(187)

466(187)

2155(84)

2729(186)

2004(187)

1800(187)

2391(84)

445(185)

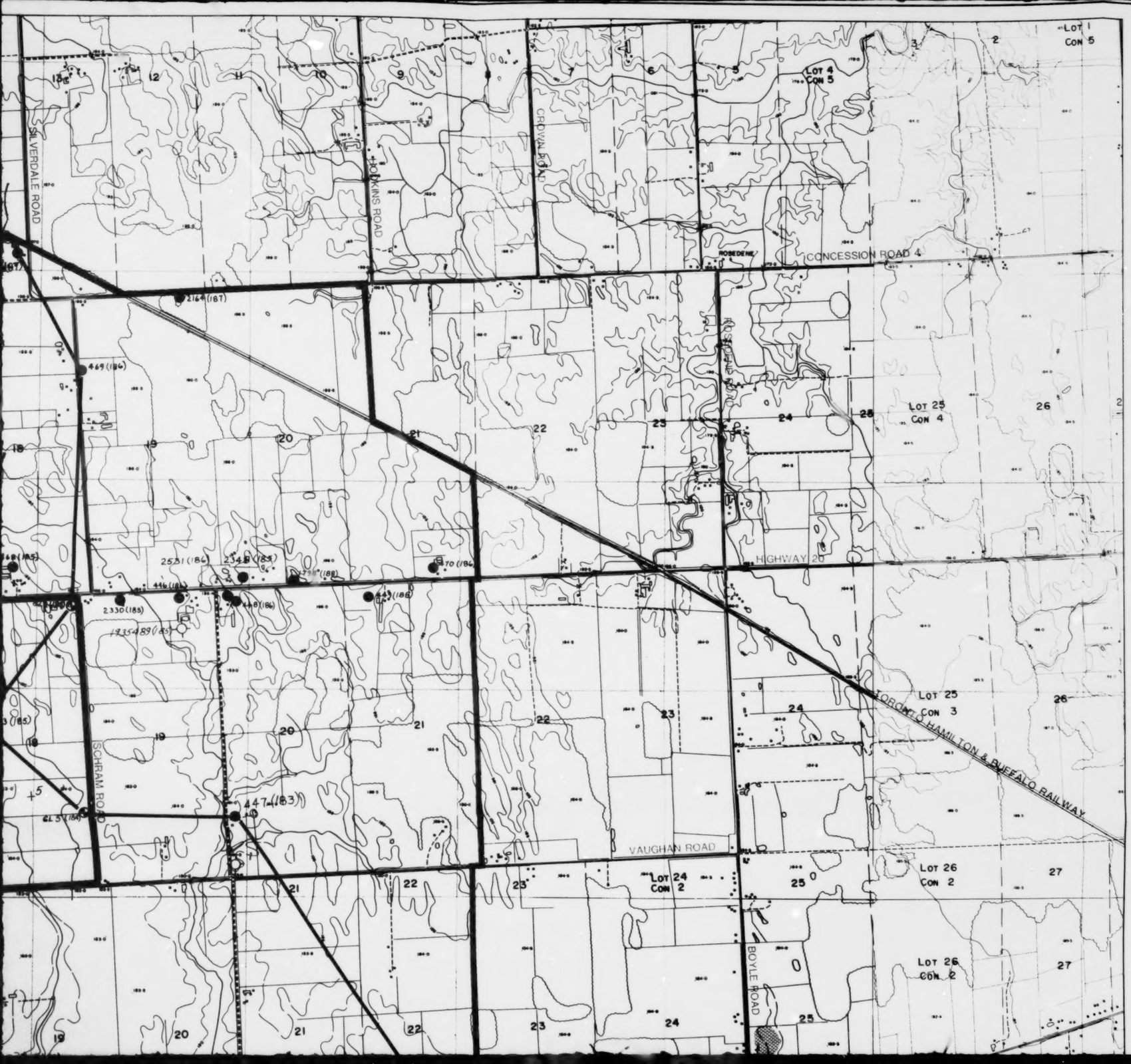
2531(184)

2348(183)

2330(183)

1935489(184)

430(182)



OWMC **Ontario Waste Management Corporation**

Consultant: Gartner Lee Associates Limited

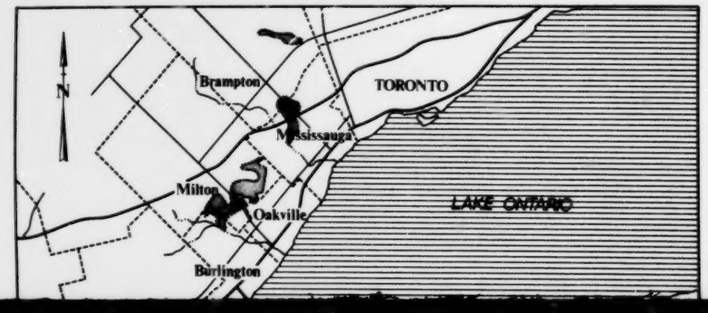
Legend:

- GL-5 — GARTNER LEE ASSOCIATES LIMITED BOREHOLE
- 253 (186) — WATER WELL WITH MINISTRY OF ENVIRONMENT NUMBER; ESTIMATED SURFACE ELEVATION IN METRES ABOVE SEA LEVEL
- \+ — GARTNER LEE ASSOCIATES LIMITED FIELD STATION
- JIL AND GAS WELL, LOCATION UNCERTAIN (NOTE WELL 6, SEE NUMBER 5 TABLE 6, SECTION 8.3)
- A — A' CROSS-SECTION

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map: **LF-9 Central**

Lot 18 and Part of Lot 17; Concession III; Township of West Lincoln; formerly in the Township of Gainsborough

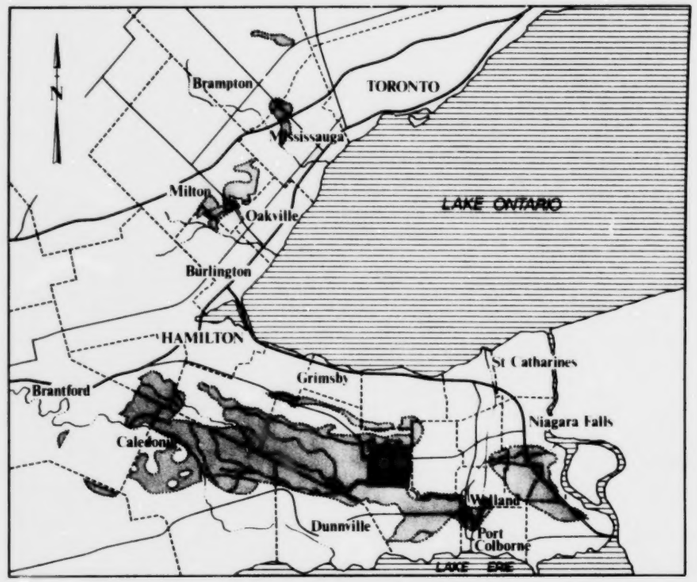


LOT 17 CON 3
SCHRAM ROAD
VAUGHAN ROAD
LOT 24 CON 2
BOYLE ROAD
CANBOROUGH ROAD
LOT 18 CON 2
DEE ROAD
HEASLIP ROAD
ELCHO ROAD
REG. RD. 68
LOT 17 CON 1
BUCKER CREEK
EAST CHIPPAWA ROAD
WILEY ROAD
REG. RD. 27
WELLAND RIVER
LOT 26 CON 1
A
A'
B
B'
430 (182)
431 (17
2306 (178)
422 (180)
1961 (183)
Contour Interval
1:10000 base mapping
Ministry of Natural Resources

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map: **LF-9 Central**

Lot 18 and Part of Lot 17; Concession III; Township of West Lincoln; formerly in the Township of Gainsborough



1000 feet 0 1000
500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Well and Borehole Locations

September 1985 **FIGURE 4**

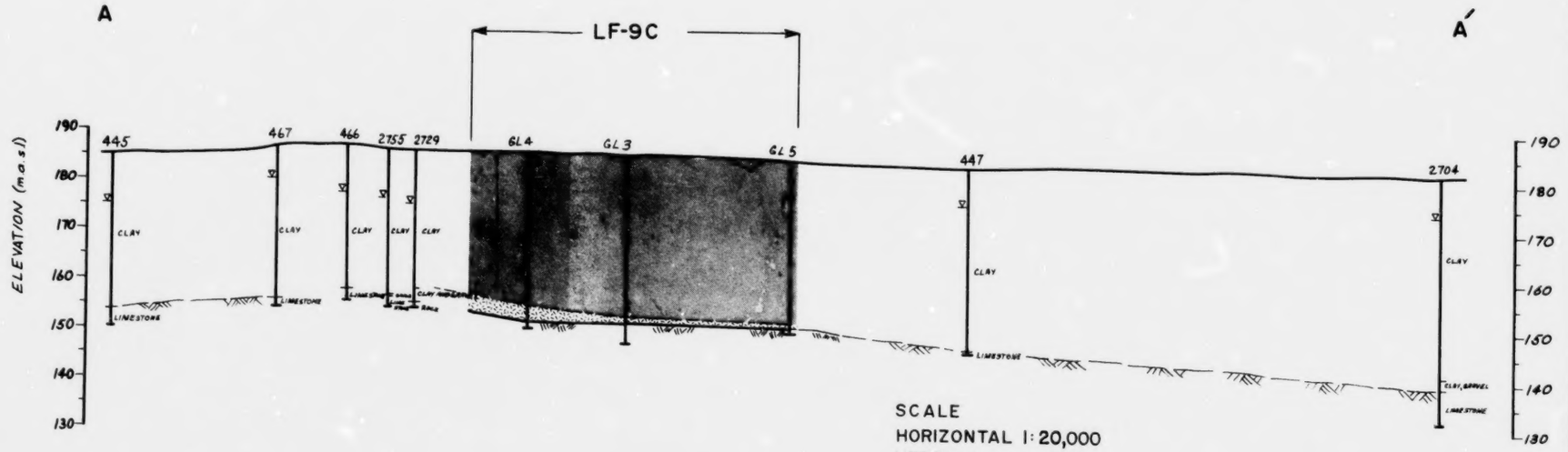
Contour Interval in Metres

1:10000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

Northwest

Looking North

Southeast



(Geologic conditions between boreholes may vary from interpretations shown)

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

Site LF-9C
CROSS-SECTION A-A'
Figure 5

LEGEND

GL 3 — Gartner Lee Associates Limited (GLAL) Borehole
417 — Ministry of Environment Water Well Record Number
▽ — Static Water Level in Well at Time of Well Construction
m.a.s.l — Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- CLAYEY SILT TO SILTY CLAY (Upper Glaciolacustrine, Halton Till, Lower Glaciolacustrine)
- SILT TILL (Lower Till)
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

NOTES - Consult Water Well Record Summary and Borehole Logs in Sections 8.1 and 8.5 for detailed descriptions.

Elevations are approximate.
Cross-Section Located in Figure 4

To accompany Phase 4A Technical Appendix
(Geologic Hydrogeologic and Geotechnical Considerations)

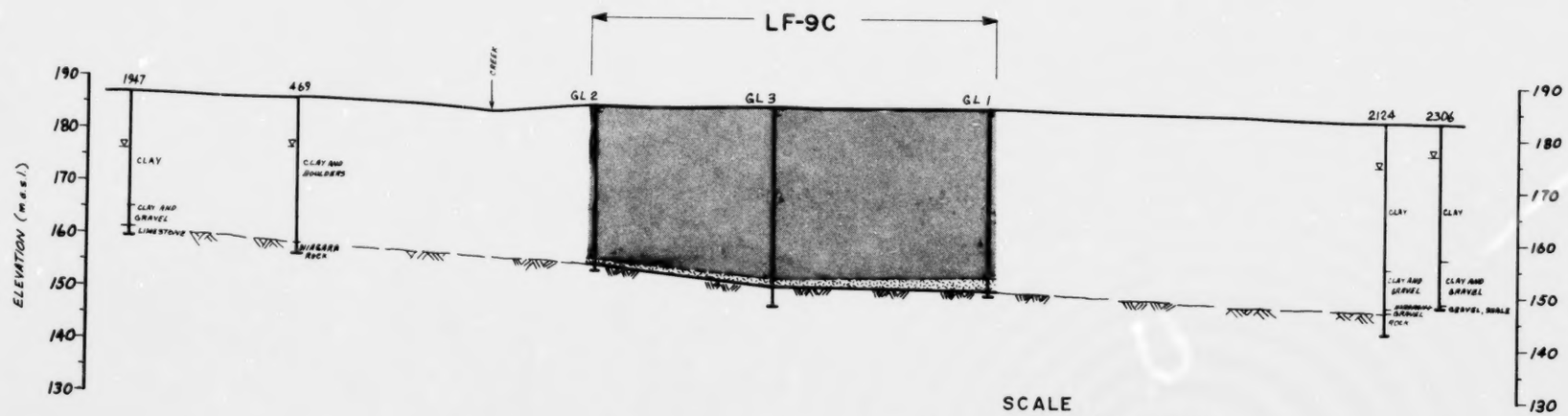
OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Northeast

Looking East

Southwest



(Geologic conditions between boreholes may vary from interpretations shown)

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

Site LF-9C
CROSS-SECTION B-B'
Figure 6

LEGEND

GL 3 — Gartner Lee Associates Limited (GLAL) Borehole
417 — Ministry of Environment Water Well Record Number
▽ — Static Water Level in Well at Time of Well Construction
m.a.s.l — Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- CLAYEY SILT TO SILTY CLAY (Upper Glaciolacustrine, Halton Till, Lower Glaciolacustrine)
- SILT TILL (Lower Till)
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

NOTES - Consult Water Well Record Summary and Borehole Logs in Sections 8.1 and 8.5 for detailed descriptions.

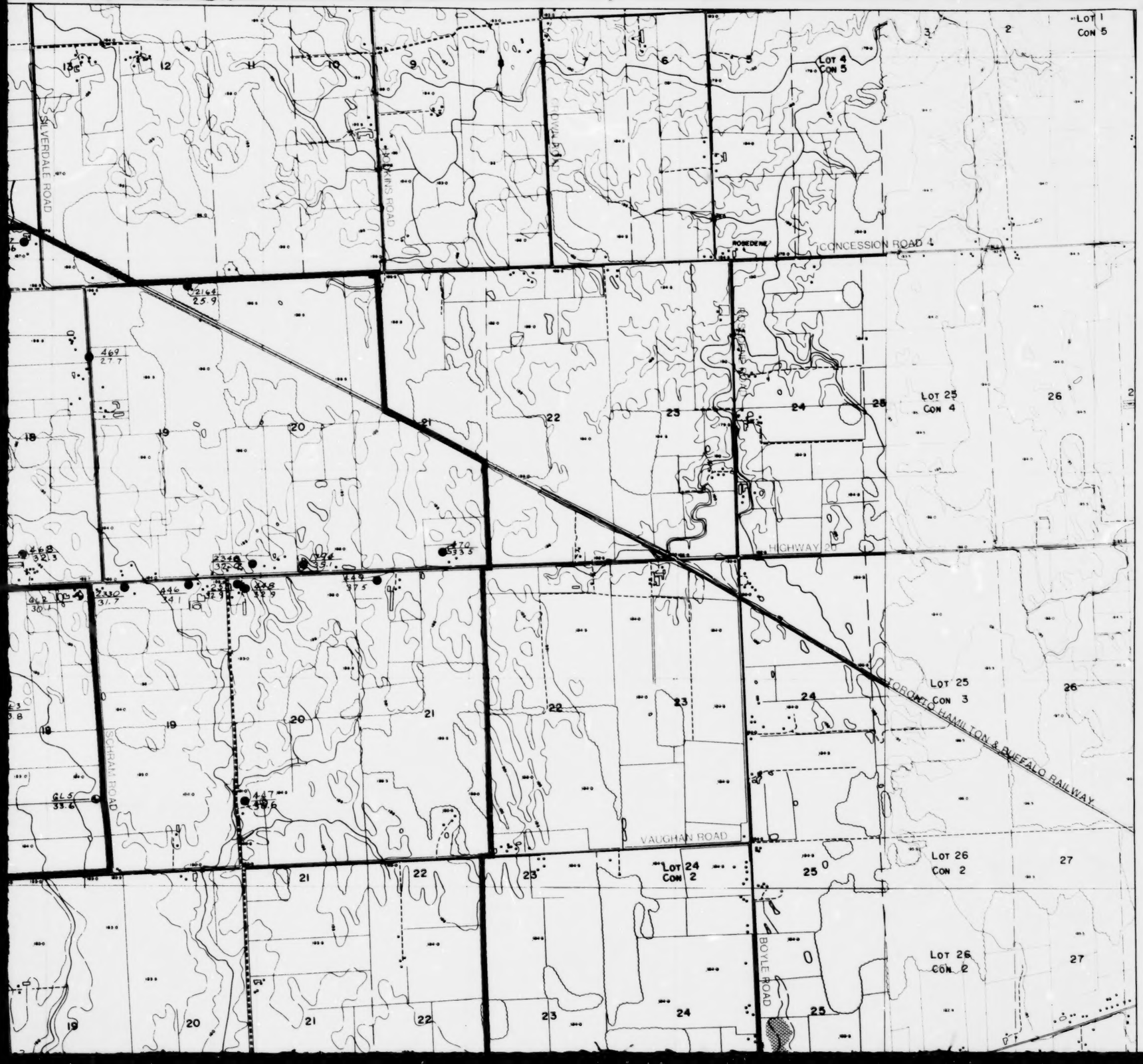
Elevations are approximate.
Cross-Section Located in Figure 4.

To accompany Phase 4A Technical Appendix
(Geologic Hydrogeologic and Geotechnical Considerations)

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

BOYD ROAD
SIDEVERDALE ROAD
JENKINS ROAD
CROWN ROAD
CONCESSION ROAD 4
ROSEDENE
HIGHWAY 20
SCHRAM ROAD
VAUGHAN ROAD
BOYLE ROAD
LOT 17 CON 5
LOT 4 CON 5
LOT 17 CON 4
LOT 17 CON 3
LOT 18 CON 2
LOT 24 CON 2
LOT CON
Lo Co
1247 25.6
2164 25.9
469 27.7
468 32.3
466 29.0
2755 29.1
2729 30.5
2804 29.9
1800 29.3
461 31.1
445 31.4
439 29.9
GL4 34.4
GL3 33.8
GL5 33.6
462 30.1
2330 31.7
446 34.1
2348 32.2
2324 33.1
448 32.9
449 37.5
470 33.5
447 33.6
430 33.8



OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

GL5 GARTNER LEE ASSOCIATES LIMITED BOREHOLE

470 WATER WELL WITH MINISTRY OF THE ENVIRONMENT NUMBER

274 THICKNESS OF THE CONFINING LAYER IN METRES

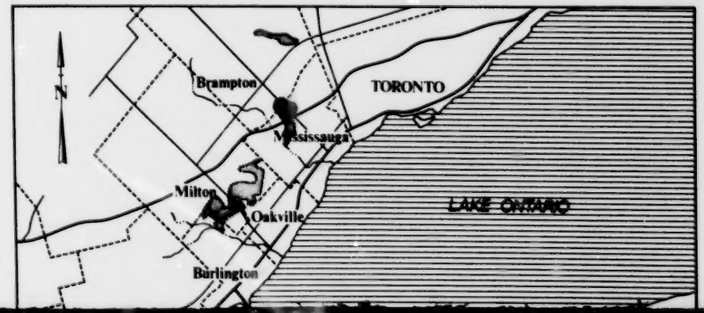
NOTE TO ACCOMPANY PHASE 4A TECHNICAL APPENDIX (GEOLOGIC, HYDROGEOLOGIC AND GEOTECHNICAL CONSIDERATIONS)

Phase 3B Acquisition Boundary

Site Vicinity Study Area Boundary

Key Map: **LF-9 Central**

Lot 18 and Part of Lot 17; Concession III; Township of West Lincoln; formerly in the Township of Gainsborough



LOT 17 CON 3

LOT 18 CON 2

LOT 17 CON 1

LOT 24 CON 2

LOT 26 CON 1

VAUGHAN ROAD

CANBOROUGH ROAD

BOYLE

WILEY ROAD

REG. RD 27

WELLAND RIVER

Contour Interval

1:10 000 base mapping p

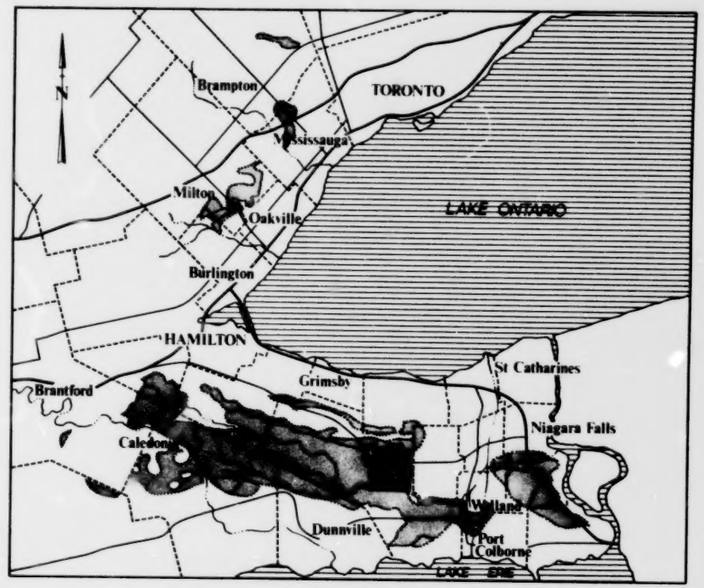
Ministry of Natural Reso

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map:

LF-9 Central

Lot 18 and Part of Lot 17; Concession III; Township of West Lincoln; formerly in the Township of Gainsborough



1000 feet 0 1000
500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

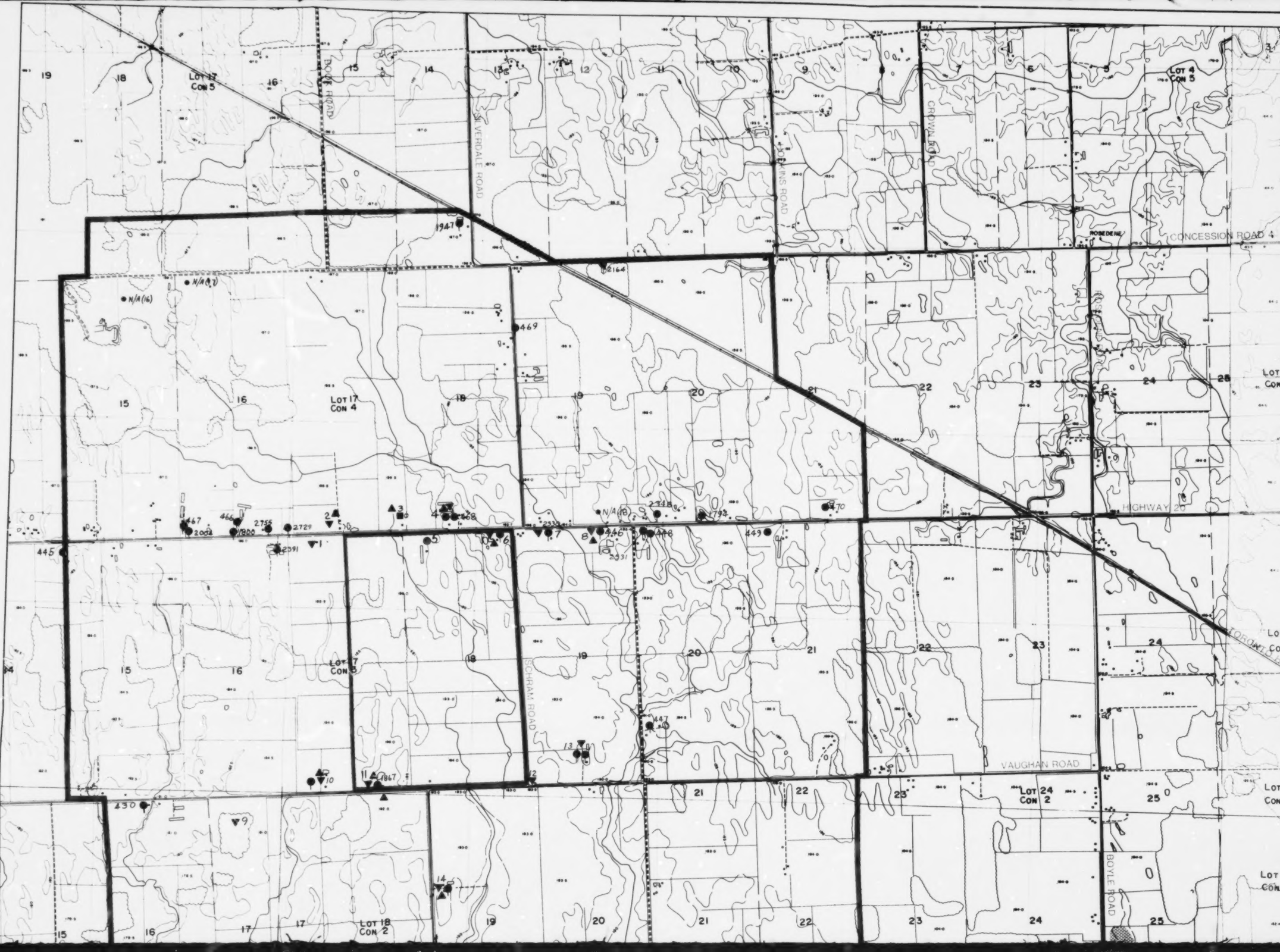
Confining Layer Thickness

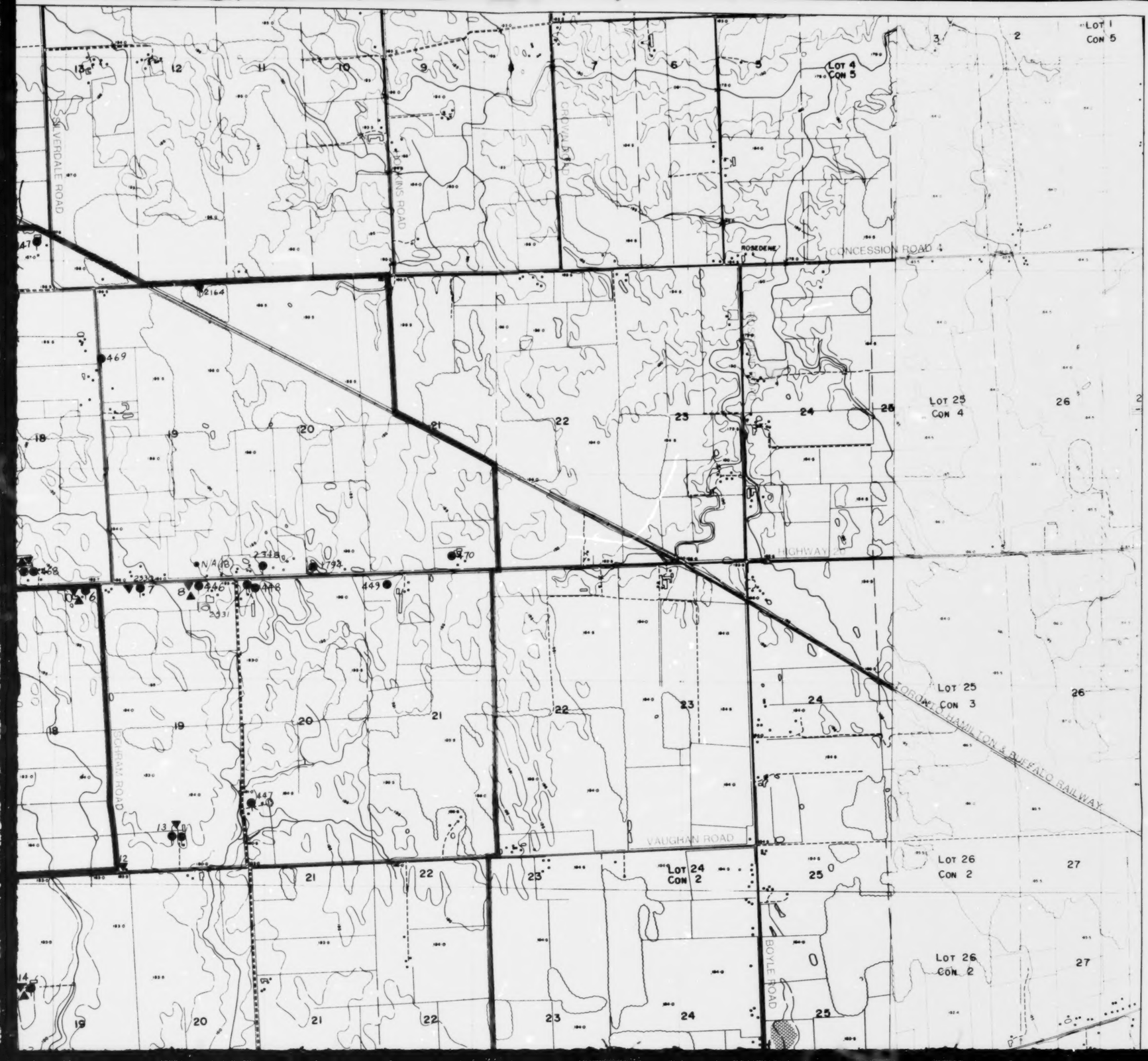
September 1985

FIGURE 7

Contour Interval in Metres

1:10000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984


LOT 17 CON 5
BOYD ROAD
SILVERDALE ROAD
ROBINS ROAD
CROWN ROAD
LOT 4 CON 5
ROSEDENE
CONCESSION ROAD 4
LOT 17 CON 4
HIGHWAY 26
LOT 17 CON 3
SCHRAM ROAD
VAUGHAN ROAD
LOT 24 CON 2
BOYLE ROAD
LOT 18 CON 2
1947
2164
469
2348
470
2755
2729
2002
1880
2391
446
448
2931
449
447
1867
430
N/A(16)
N/A(17)
N/A(18)



OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

- ● , ● DRILLED WELL COMPLETED IN OVERBURDEN/BEDROCK
- ■ DUG OR BORED WELL
- FLOWING CONDITIONS
- / , X UNUSED/ABANDONED WELL
- ▲ DUGOUT OR POND
- ▼ CISTERN
- \+ ADDITIONAL FIELD INFORMATION
- ●N/A INFORMATION NOT AVAILABLE

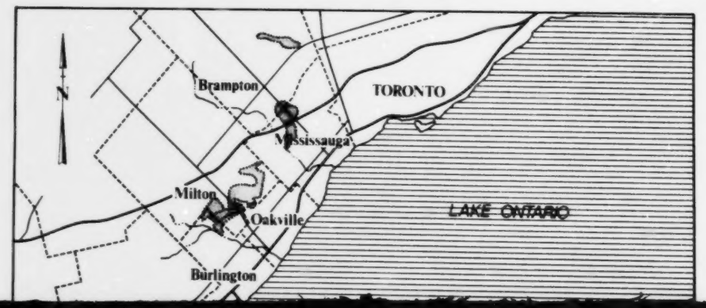
NOTES: Details for wells with Ministry of Environment numbers (3 and 4 digits) are provided in the Summary of Water Well Data (Table 4, Section 8.1). Other numbers accompany wells, cisterns, dug outs or ponds, and locations where additional field information was gathered. Details for these are provided in the Summary of Site Interview Data (Table 6, Section 8.3)

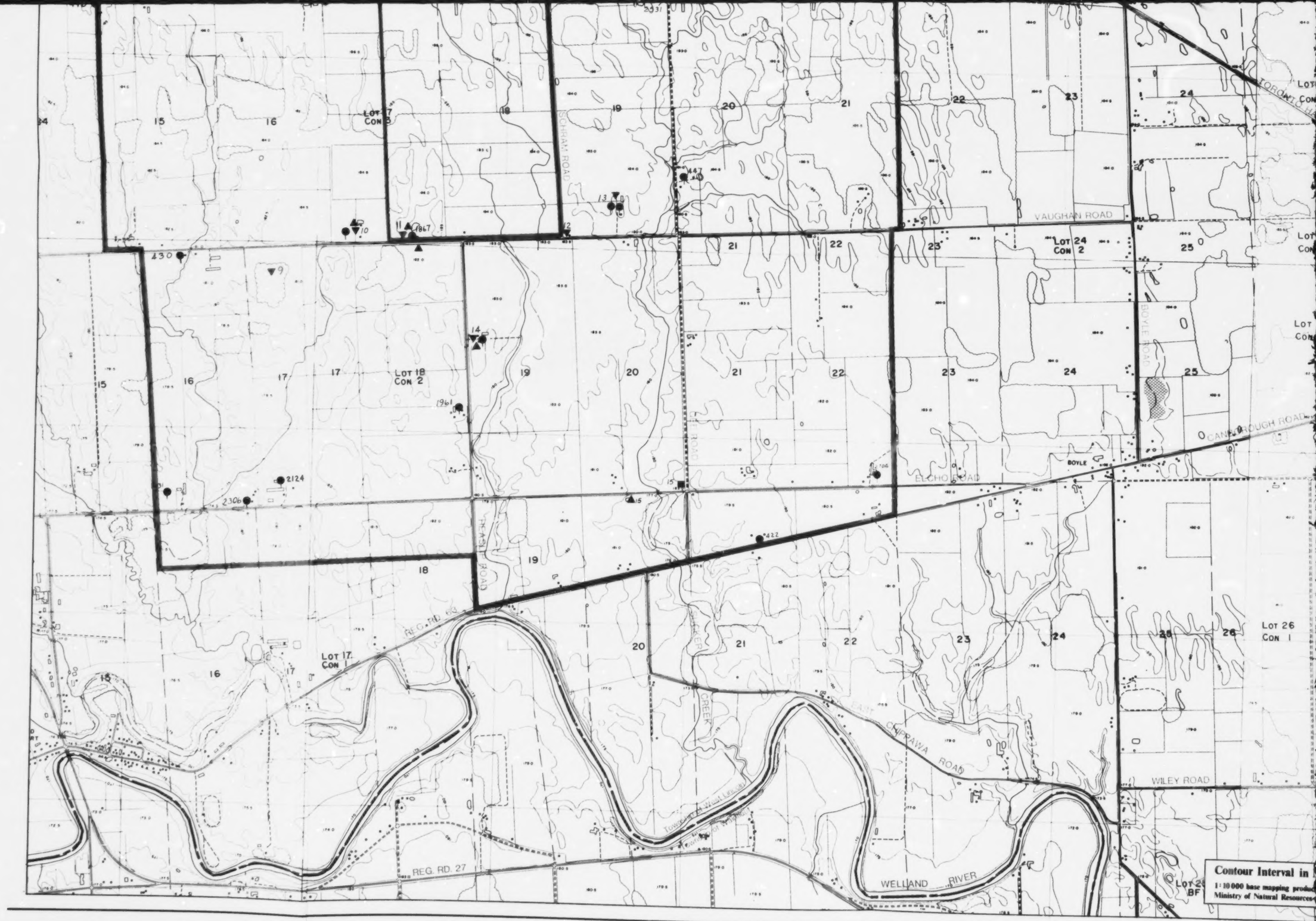
Phase 3B Acquisition Boundary **Site Vicinity Study Area Boundary**

Key Map:

LF-9 Central

Lot 18 and Part of Lot 17; Concession III; Township of West Lincoln; formerly in the Township of Gainsborough



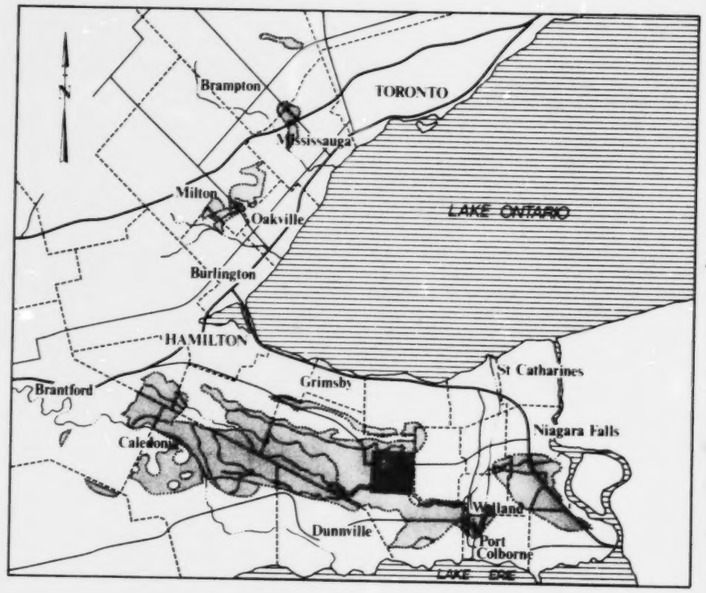

LOT 17
CON 3
ISCHAM ROAD
VAUGHAN ROAD
LOT 24
CON 2
BOYLE ROAD
LOT 18
CON 2
PEARL ROAD
ELCHO ROAD
CANBOROUGH ROAD
BOYLE
LOT 17
CON 1
REG. RD. 27
EAST CHIPPAWA ROAD
WILEY ROAD
LOT 26
CON 1
WELLAND RIVER
Contour Interval in
1:10000 base mapping produc
Ministry of Natural Resources

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundar

Key Map:

LF-9 Centra

Lot 18 and Part of Lot 17; Concession III; Township of West Lincoln; formerly in the Township of Gainsborough



1000 feet 0 1000
500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Ground Water Use

September 1985

FIGURE 8

Contour Interval in Metres

1:10 000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

Number/
Numéro
3

SITE SELECTION PROCESS - PHASE 4A

TECHNICAL APPENDIX LF-1E

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS

A REPORT PREPARED FOR
THE ONTARIO WASTE MANAGEMENT CORPORATION
BY
GARTNER LEE ASSOCIATES LIMITED

THIS REPORT IS ONE OF EIGHT TECHNICAL APPENDICES DESCRIBING GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS OF THE CANDIDATE SITES. IT SUPPORTS THE COMPARATIVE EVALUATION STUDY WHICH IS ENTITLED "SITE SELECTION PROCESS; PHASE 4A, SELECTION OF PREFERRED SITE(S), GEOLOGIC, HYDROGEOLOGIC AND GEOTECHNICAL CONSIDERATIONS.

SEPTEMBER 1985.

PROJECT NO: 85-S18.3

Gartner Lee
Associates Limited

Gartner Lee Associates Limited

Consulting Engineering
Geologists
Biologists and
Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-477-8400
Telex-06-986278

September 11, 1985.

Dr. B.D. Mitchell,
Director of Corporate Planning
and Development,
Ontario Waste Management Corporation,
2 Bloor Street West,
11th Floor,
Toronto, Ontario,
M4W 3E2.

Attention: Mr. J.G. Micak,
Manager,
Environmental Projects

Dear Dr. Mitchell:

Re: Site Selection Process - Phase 4A
Technical Appendix LF-1E - Geologic, Hydrogeologic,
and Geotechnical Considerations

Enclosed is our final report on the Geologic, Hydrogeologic and Geotechnical Considerations at Candidate Site LF-1E. Similar reports prepared for each of the other candidate sites will form the basis for site comparisons.

Thank you for allowing our company to be of service.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

Grant Anderson

E.G. Anderson, P.Eng.,
Project Director.

KJG:jcm
Enclosures.

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STUDY TEAM

This report was prepared under the overall direction of Grant Anderson, P.Eng., Project Director and Gunther Funk, Project Manager. Major contributing authors were:

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Field Co-ordination	Norbert Woerns

1.0 INTRODUCTION

1.1 BACKGROUND

The Ontario Waste Management Corporation's (OWMC) site selection process to locate facilities for treating hazardous wastes and disposing the treated waste residues has been a phased process which began in 1981. Initial studies identified 261 hydrogeologic areas throughout southern Ontario which were grouped into six zones. Within the Golden Horseshoe, Zone 1 and 2 lands were considered most favourable for facility siting. Twenty candidate areas were identified within the Zone 1 and 2 lands in the Golden Horseshoe in 1983. A total of 152 sites were identified in these twenty candidate areas in 1984 and this number was subsequently reduced in stages to sixteen potential sites and finally to eight candidate sites through the application of various constraints, screening processes, and ranking systems based on multidisciplinary factors. A more complete discussion of the site selection process is provided in the comparative evaluation study (Gartner Lee Associates Limited, 1985).

The present stage of study is the comparative assessment of the eight candidate sites. This Gartner Lee Associates Limited (GLAL) report documents and interprets available geologic, hydrogeologic, and geotechnical information for Site LF-1E and serves as the data source for input to the site comparison study. The candidacy of this site is based on the potential development of either a total treatment facility including a landfill or a landfill alone. The Phase 3B preliminary assessment of this site was based primarily on

existing data (GLAL 1984b). Phase 4A investigations described in this report add significantly to the geologic, hydrogeologic, and geotechnical data bases.

1.2 OBJECTIVES AND SCOPE

The objective of this report is to provide data for Site LF-1E to accommodate comparisons with the other siting alternatives. This objective has been met through additional investigations. The existing data base has been upgraded where possible and six boreholes have been drilled at selected locations on the site. Each of the boreholes has been continuously sampled to provide detailed geologic logs and soil samples. Boreholes were not instrumented and were grouted on completion.

1.3 LOCATION

Site LF-1E is located in the east-central portion of the Niagara Peninsula. It is shown together with the seven other candidate sites in Figure 1 and is presented in greater detail in figures in the map pockets at the rear of the report.

The site under consideration in this Technical Appendix covers approximately 273 hectares (ha) and includes Lots 5, 6, and 7, Concessions 2 and 3, City of Niagara Falls (formerly in the Township of Crowland), Regional Municipality of Niagara. It is bounded on the north and south by Carl and Schisler (Regional Road 27) roads respectively and on the east and west by Crowland Avenue and the Conrail line respectively. The site is roughly centered in a study area of about 2475 ha.

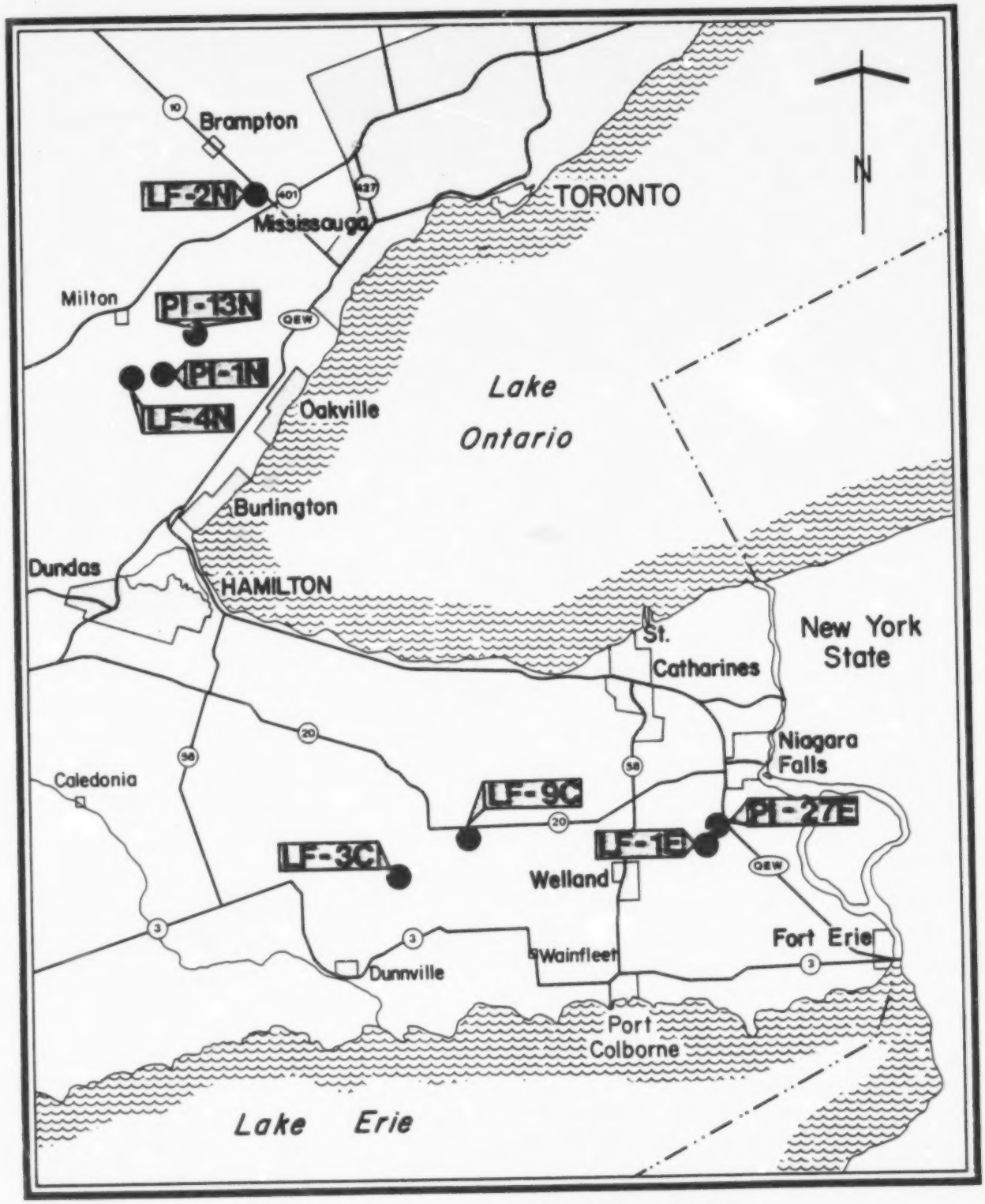


FIGURE 1 LOCATION OF CANDIDATE SITES

The site is located within the corporate limits of the City of Niagara Falls and is about 2 km south of the Welland River, 3 to 4 km west of the Queen Elizabeth Highway (QEW), and approximately 1 km southwest of Site PI-27E.

2.0 METHODOLOGY

The methodology employed in the collection, compilation, and interpretation of the information base presented in this technical appendix report is described below and illustrated in Figure 2.

2.1 DATA COLLECTION

The following sources of information were used:

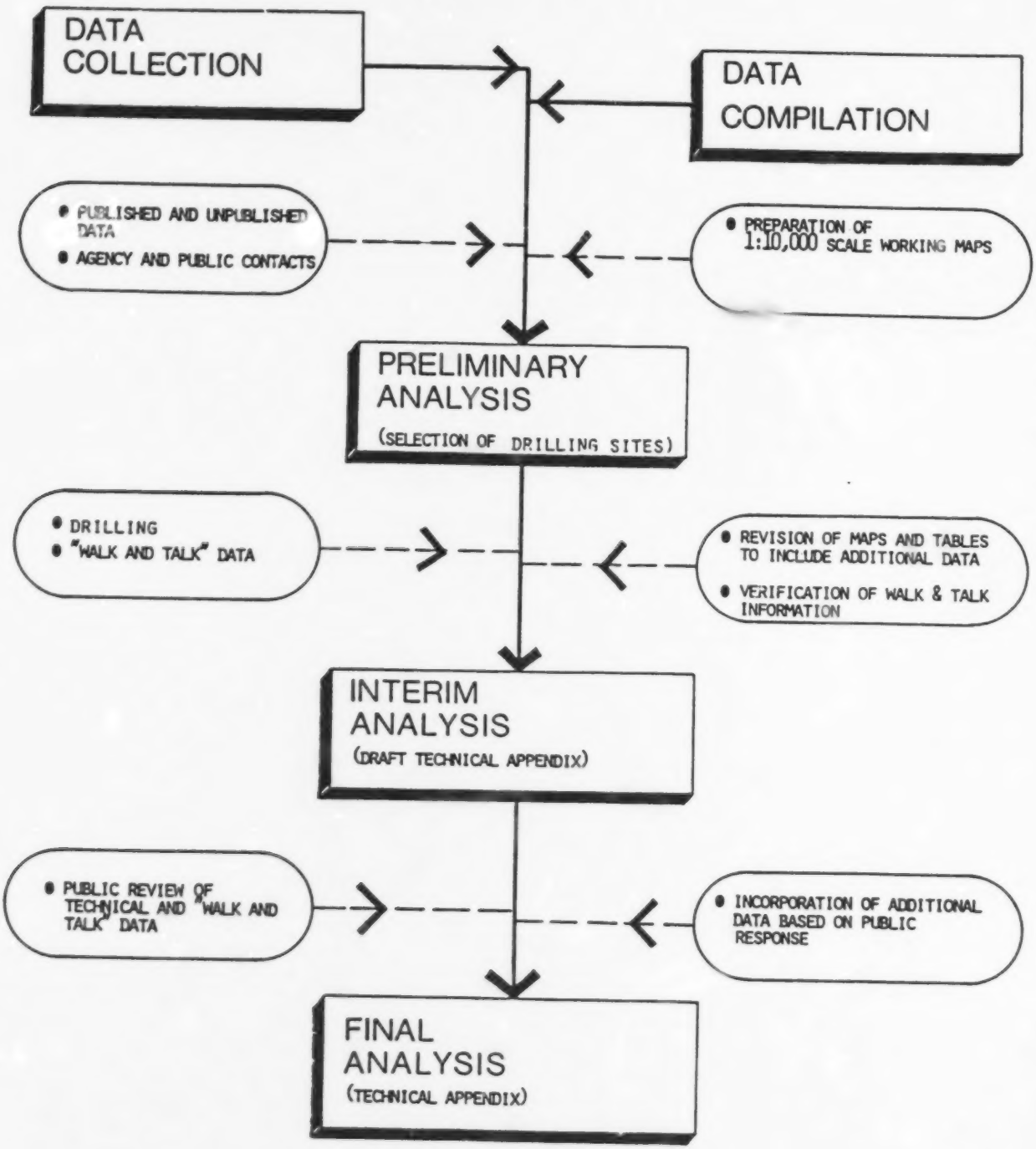
- water well and borehole records; published and unpublished reports, maps and 'open file' reports;
- interviews with government agency personnel and local residents; and
- onsite drilling and field survey results.

2.1.1 DATA BASE

Numerous reports and maps which contain both regional and local information on the geology and hydrogeology of the candidate sites were assembled during the earlier phases of the site selection process. Reports specific to this site are referenced in the text and are listed in Section 7.0. Supplementary

Figure 2

Methodology Flow Chart


DATA COLLECTION
DATA COMPILATION
• PUBLISHED AND UNPUBLISHED DATA
• AGENCY AND PUBLIC CONTACTS
• PREPARATION OF 1:10,000 SCALE WORKING MAPS
PRELIMINARY ANALYSIS
(SELECTION OF DRILLING SITES)
• DRILLING
• "WALK AND TALK" DATA
• REVISION OF MAPS AND TABLES TO INCLUDE ADDITIONAL DATA
• VERIFICATION OF WALK & TALK INFORMATION
INTERIM ANALYSIS
(DRAFT TECHNICAL APPENDIX)
• PUBLIC REVIEW OF TECHNICAL AND "WALK AND TALK" DATA
• INCORPORATION OF ADDITIONAL DATA BASED ON PUBLIC RESPONSE
FINAL ANALYSIS
(TECHNICAL APPENDIX)

information was collected with the co-operation of government agencies. This information includes:

- copies of original water well records obtained from the Ministry of the Environment.

- copies of oil and gas well records obtained from the Ministry of Natural Resources.

- copies of borehole records and water well survey information obtained from the St. Lawrence Seaway Authority.

These data are presented in Section 8.0. Copies of the data are on file.

2.1.2 INTERVIEWS

Additional information regarding site geology and water use was obtained during interviews with government agency personnel and local residents. The results of the interviews are presented in the summaries prepared for agency meetings (by GLAL) and on resident interview forms (prepared by Ecologistics Limited). Meetings were held with the local public interest group made up of residents and other interested individuals. The group identified items of geologic and hydrogeologic interest. The summaries of meetings and the interview forms are on file. Local water use information summarized from the interview forms is tabulated in Section 8.3.

2.1.3 DRILLING AND FIELD SURVEY RESULTS:

Borehole locations were selected based on preliminary analyses of available data and input from the public. Five boreholes

were completed at selected locations on site and one borehole was located offsite to investigate the expected character of the geologic materials. Drilling and sampling procedures are presented in the document entitled "Phase 4A Drilling and Sampling Activities and Protocol" (GLAL 1984a) and the detailed methods employed during this study are summarized in Section 8.7.

The drilling program involved the collection of continuous samples from boreholes. These samples were photographed and described in the field, placed in suitable containers, and shipped to the Ontario Geological Survey in Toronto for storage. Split spoon samples were taken at 1.5 m intervals to obtain standard penetration resistance values and samples for moisture content determinations in order to carry out preliminary geotechnical assessments. Detailed borehole logs were prepared based on the field descriptions and on subsequent re-examination of the samples in storage. These logs are presented as part of the supporting information package in Section 8.4.

2.2 DATA COMPILATION AND ANALYSIS

Data compilation and analysis has proceeded in a staged fashion which is depicted in Figure 2. In the initial work, data such as water well information were compiled in summary tables and illustrated on a series of working maps and cross-sections at a scale of 1:10 000. Maps included plots of:

- data point locations (all sources);
- geology (Ontario Geological Survey reports, constraint mapping results from Phase 3B and Ministry of the Environment maps and reports;

- bedrock elevations (water well and oil and gas well data);
- confining layer thickness (water well and borehole data);
- aquifer thickness (water well data);
- aquifer information (water well data); and
- anomalies such as granular zones (water well and borehole data).

These maps were used to establish the geographic distribution of existing data points and to confirm, at a more detailed scale, the preliminary interpretation of geologic and hydrogeologic conditions as presented in the Phase 3B documentation (GLAL 1984b). Tentative drilling locations were then identified based on these preliminary analyses.

Following the selection of the tentative drilling locations, GLAL personnel met with interested parties to present the results of the preliminary analyses and to discuss the purpose and scope of the Phase 4A program. Additional information on local geologic and hydrogeologic conditions was collected during these meetings. Landowners and tenants were contacted at this time to obtain permission to drill on their properties and proposed drill site locations were modified based on local inputs.

A separate data collection program commonly referred to as the "Walk and Talk" survey was also undertaken. During this survey, individual residents were interviewed by personnel from Ecologistics Limited and the results were presented in a questionnaire format. Among the multidisciplinary questions were several which were provided by Gartner Lee Associates Limited

and which related specifically to water supply and use. The collection of ground water information and related water use data was limited primarily to the site and to adjacent areas.

With the completion of the drilling and public survey programs, the working maps were revised to incorporate the additional information that was collected. This technical appendix presents the interpretation of geologic, hydrogeologic, and geotechnical conditions at Site LF-1E to date. Draft copies of the data summaries were circulated to the local interest groups as a check for completeness and accuracy.

3.0 REGIONAL GEOLOGY AND HYDROGEOLOGY

The geology and hydrogeology of the Niagara Peninsula are summarized and discussed in a previous report prepared for the Ontario Waste Management Corporation (GLAL 1984b). This section is based on this report and the reader is referred to it for more detail and for a complete list of references.

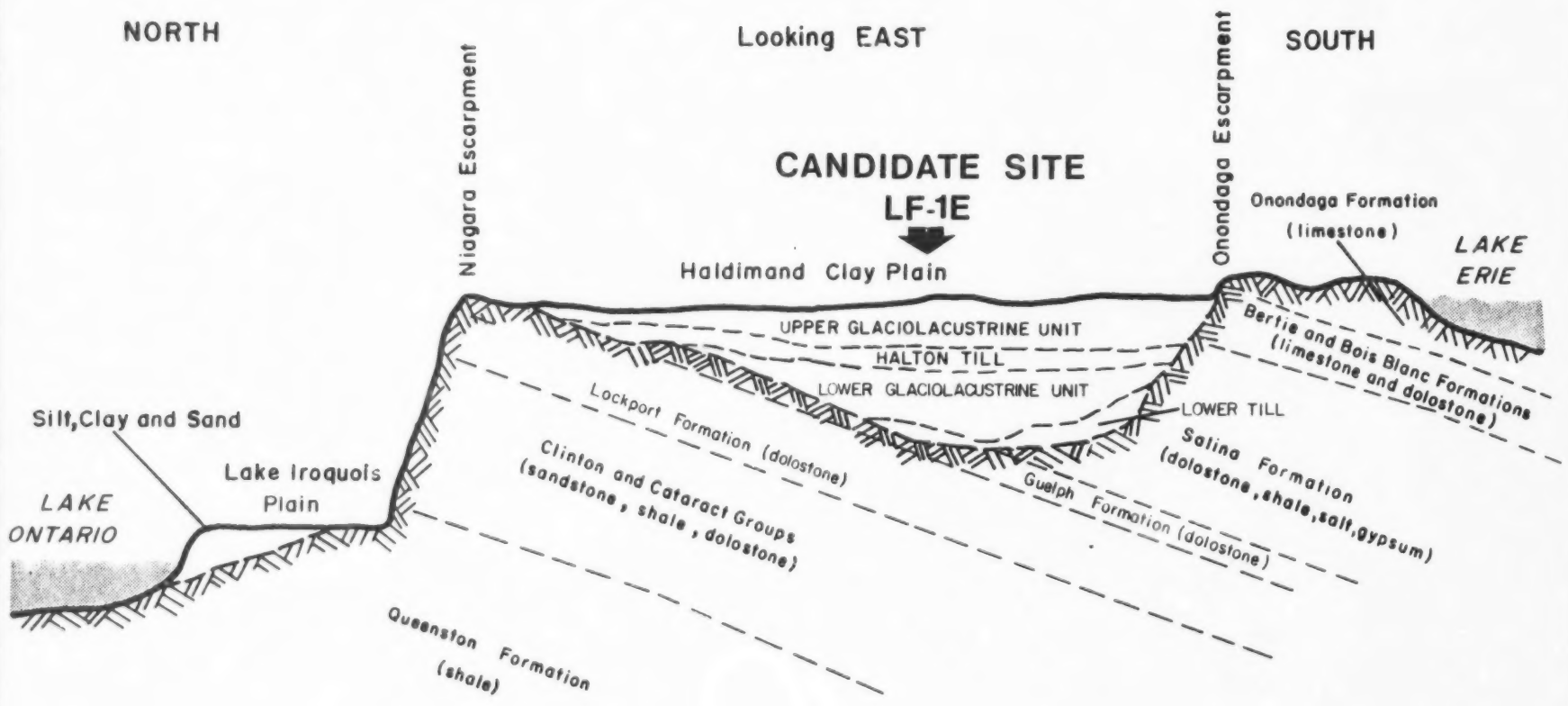
3.1 REGIONAL GEOLOGY

3.1.1 BEDROCK GEOLOGY AND OVERBURDEN THICKNESS

Bedrock in the Niagara Peninsula consists of a sequence of sedimentary formations which dip slightly to the south. This southerly dip exposes the various formations on the buried bedrock surface in east-west trending bands. Figure 3 shows the approximate location of Site LF-1E on a generalized cross section of the Peninsula and names the major geologic units.

FIGURE 3

Cross–Section Sketch Through The Eastern Niagara Peninsula



Reference: Adapted from G.L.A.L. 1984c

NOT TO SCALE

Gartner Lee Associates Limited

The site is located over a bedrock depression of regional dimensions between the Niagara and Onondaga escarpments near the contact of the Guelph and Salina formations. Depths to bedrock in the vicinity of the site are generally in the 20 to 30 m range.

3.1.2 QUATERNARY GEOLOGIC HISTORY

Regional overburden units are indicated in Figure 3. From oldest to youngest they are (1) a lower till directly over the bedrock, (2) a lower glaciolacustrine unit, (3) an upper till (Halton), and (4) an upper glaciolacustrine unit. The geologic sequence of events associated with these deposits began with a major ice advance over the Niagara Peninsula which deposited the lower till. This ice advance occurred about 23 000 years ago and the ice remained there until it withdrew northward approximately 14 000 years ago. Deposition of the lower glaciolacustrine unit occurred in a subsequent glacial lake. A brief readvance of the ice into the glacial lake resulted in the deposition of the Halton Till about 13 000 to 12 000 years ago. As the Halton ice withdrew, the lake re-formed in front of it and the upper glaciolacustrine unit was deposited. Following drainage of this lake, the upper glaciolacustrine deposits have been subjected to weathering and erosion to produce the present landscape.

3.1.3 QUATERNARY GEOLOGY:

Generalized descriptions of each of the major overburden units are presented to provide a regional perspective on their characteristics and distribution. These are also used to place the discussion of the site geology into proper context.

A sandy silt to silty sand till occurs above the bedrock

at scattered locations throughout the Niagara Peninsula (Feenstra 1974, 1975, 1981, Barnett 1975) and it is generally acknowledged to be the Wentworth Till. This unit is also referred to in the literature as the "lower till" and this term is used here. The lower till is encountered in all GLAL boreholes and is inferred in more than half the water well logs in the vicinity where it is identified as 'clay and stones', 'clay and gravel' and/or 'hardpan'. Water well records report sand and gravel occurrences between the lower till and bedrock. These basal deposits occur regionally and are summarized in previous OWMC reports (GLAL 1984b,c). Since none of the GLAL boreholes on this site detected basal granular deposits it is considered that the granular deposits are discontinuous.

Owen (1969, 1972) and Feenstra (1981) have described a lower glaciolacustrine deposit between the lower till and the Halton Till. They note a regional composition which includes clays, silts, and sands and indicate that this layered deposit is often only a few metres thick. The lower glaciolacustrine unit occurs between the two tills in all GLAL boreholes and tends to be silty to clayey in texture.

The Halton Till occurs between the upper and lower glaciolacustrine units over most of the Niagara Peninsula. The Halton Till is generally buried beneath upper glaciolacustrine deposits and is not usually exposed at surface. It may outcrop in valleys where the upper glaciolacustrine deposit is eroded, where the Halton Till thickens in moraines, or where the bedrock is exposed. Till composition in the central portion of the Peninsula reflects the silts and clays of the underlying glaciolacustrine deposits which are incorporated into it. Feenstra (1981) notes that the typically clayey and silty

Halton Till deposits are interspersed with sand and silty sand lenses on several moraines in the Niagara Peninsula. Portions of the Halton Till may be waterlain according to Feenstra (1981).

The upper glaciolacustrine unit consists primarily of silts and clays which occur at the surface over a large portion of the Niagara Peninsula and which constitute the Haldimand Clay Plain. Feenstra (1981) describes it as a "massive or stratified (varved in places) silty clay....with generally more than 50% clay and 5% sand". Feenstra (1975) also notes that this unit has been observed up to 16 m thick. Thin lenses and laminae of sand have been observed within the upper 2 m of the upper glaciolacustrine unit at several locations in the region. Glaciolacustrine deposits immediately underlie the study area and most of the area in the vicinity. The upper and lower glaciolacustrine units and the Halton Till are considered to comprise the 'clay' deposits which account for most of the overburden materials described in the water well logs (Section 8.1).

Alluvial deposits occur in association with flood plains in the region and are confined laterally and from below by the upper glaciolacustrine unit. They tend to be fine-textured reflecting available source materials and low to moderate stream gradients.

3.2 REGIONAL HYDROGEOLOGY:

The regional distribution of hydrostratigraphic units is illustrated in Figure 3. The Salina and Guelph formations are major regional aquifers and their contact appears to underlie the site. The Guelph Formation produces the better yields and

the better water quality in the area although the water may locally be mineralized. Water quality in the Salina Formation is generally poor due to the presence of evaporites (primarily gypsum) in the shale sequence. Hydraulic conductivity in both formations is usually best developed as a result of fracturing and solution enhancement in the upper few metres of bedrock, immediately below the overburden-bedrock contact.

Basal sand and gravel deposits are commonly reported in water well records and are occasionally sources of water supply to drilled wells, however the lower till itself is considered not to have water-bearing potential because of its relatively low hydraulic conductivity. Where basal granular deposits occur, they are considered to be in good hydraulic connection with the bedrock.

The upper and lower glaciolacustrine units and the Halton and lower tills comprise a single hydrostratigraphic unit of regional extent which is referred to in this report as the confining layer. Downward hydraulic gradients generally exist across this unit, however ground water flow rates and quantities are very small. Hydraulic conductivities reported in similar materials by Desaulniers et al. (1981) near Wainfleet average approximately 3.0×10^{-10} m/s and several values in glaciolacustrine deposits near Lewiston, New York were also in the 10^{-10} m/s range (Wehran Engineering P.C. 1983). No drilled wells are known to obtain water from the confining layer.

The surficial, fractured portion of the confining layer may extend to depths which range up to several metres. Occasional dug and bored wells reportedly obtain water supplies

from this zone on a local basis. Saturated fracture systems and granular laminations within the glaciolacustrine deposits are considered to be the source of water to such wells. In view of the fine-textured character of the deposits and the limited porosity of the fractures, yields to most shallow dug and bored wells are expected to be low and users likely rely on well-bore storage for periods of peak use.

Alluvium may provide water supplies to shallow dug and bored wells at some flood plain locations.

4.0 SITE GEOLOGY AND HYDROGEOLOGY

The discussions of geology and hydrogeology at Site LF-1E take into account the regional data as well as the new borehole information. In addition, data from formal and informal field interviews are integrated into this analysis. Figure 4 (in map pocket) provides locations of field data and indicates the locations of cross-sections.

Results from the GLAL borehole program are used to confirm the hydrostratigraphy and to evaluate the predictability and uniformity of subsurface conditions. Hydrogeologic discussions are based on the borehole geology and on such additional sources of information as water well and borehole records and water use data provided by local residents. Table 1 presents local geologic and hydrostratigraphic units which are defined for the site and the vicinity. This table provides the framework for the discussions that follow.

4.1 SITE GEOLOGY

Six continuously sampled boreholes were drilled to investigate the subsurface geology. Four of these boreholes were cored into bedrock, one terminated in the lower till, and one terminated after penetrating about 6 m of lower till (possibly at the bedrock surface). GLAL borehole locations are shown in Figure 4 along with water wells, oil and gas wells, and St. Lawrence Seaway Authority boreholes. Logs of the boreholes and summaries of other subsurface data are included in Section 8.0. Cross-sections through the study area are presented in Figures 5 and 6 (in map pocket). The geologic names in the borehole logs (e.g. Halton Till, lower glaciolacustrine unit) are used to relate local geology to the established geologic framework and are based on published descriptions. Geologic descriptions on the cross-sections are simplified for presentation.

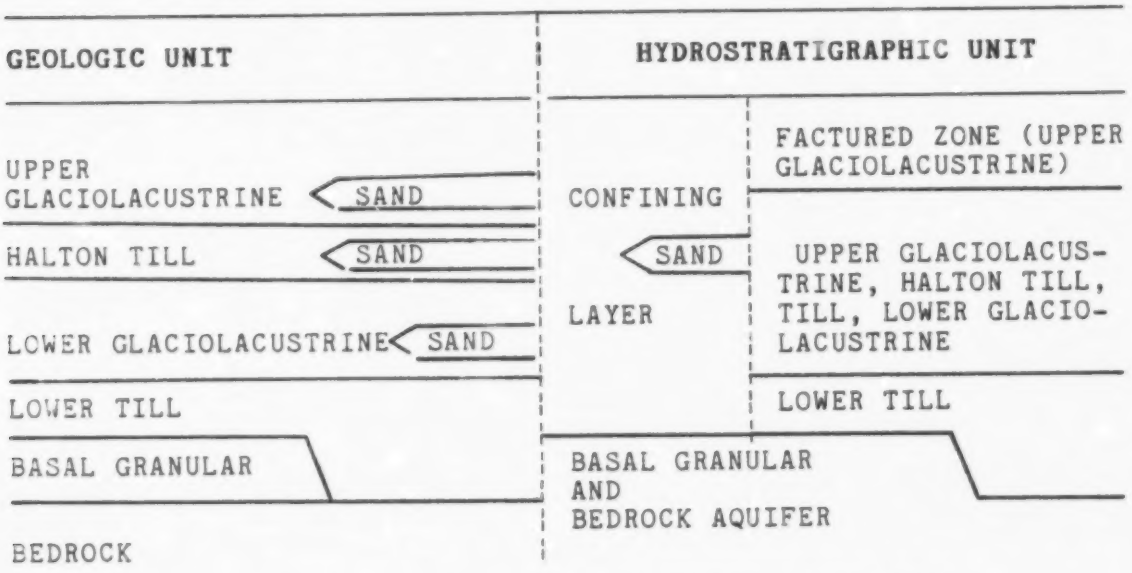
4.1.1 TERRAIN

Site LF-1E is located on a portion of the Haldimand Clay Plain (Chapman and Putnam 1966) which is flat to gently rolling. Elevations range from about 182 m (above sea level) along the southern site boundary to about 180 m along the northern boundary. A small knoll, known locally as 'Walnut Hill', immediately east of the site (about midway along the eastern boundary) rises to an elevation of approximately 185 m. Drainage is toward the Welland River via Lyons Creek, however water courses are not well defined. Small deposits of alluvium are present at the extreme southern edge of the site.

4.1.2 BEDROCK GEOLOGY AND DRIFT THICKNESS

GLAL boreholes which were cored into bedrock encountered dolostone, shale, and shale with gypsum. These descriptions

TABLE 1: SUMMARY OF LOCAL GEOLOGIC AND HYDROSTRATIGRAPHIC UNITS



are similar to those provided by Telford et al. (1976) and are considered to indicate both the Salina and Guelph formations. The Guelph-Salina contact lies slightly north of the site according to Telford et al. (1976), however present evidence suggests that the contact should be moved slightly southward to pass through the site. Bedrock elevations range from about 144 to about 154 m and there is evidence of a gentle bedrock depression through the central and west-central parts of the site. Overburden thicknesses range from about 26 to 36 m in the GLAL boreholes.

4.1.3 BASAL GRANULAR UNIT

No basal granular deposits were encountered in the GLAL bore-

holes, however several water well records in the study area note the occurrence of sand and gravel deposits on the bedrock surface. It is considered that the basal granular unit is discontinuous beneath the site and the study area.

4.1.4 LOWER TILL

A sandy silt to silt lower till was encountered between the bedrock and the lower glaciolacustrine unit in the GLAL boreholes. This lower till is also inferred in water well logs which report 'stony clay', 'clay and gravel' and 'hardpan'. GLAL borehole logs indicate that this till directly overlies the bedrock. The lower till is typically brown to dark grey in colour, saturated, and shows minor textural variability between boreholes. Inclusions of fine sand are noted in Boreholes GL1, GL4, and GL6. The unit ranges in thickness from 3.3 to 9.3 m in the GLAL boreholes.

4.1.5 LOWER GLACIOLACUSTRINE UNIT

This unit ranges from zero to 8.1 m in thickness in the GLAL boreholes across the site. It is absent in Boreholes GL3 and GL4 in the northwest and southeast portions of the site respectively. In these areas, the bedrock rises, the lower till thickens slightly and the Halton Till occurs directly on the lower till. The lower glaciolacustrine unit is thickest in Borehole GL6 at Walnut Hill. It has a silty clay to clayey silt texture except in Borehole GL5 where it consists of interbedded silt, fine sand, and silty clay.

4.1.6 HALTON TILL

The Halton Till was encountered in all the GLAL boreholes and it may be inferred in some of the St. Lawrence Seaway Authority boreholes which occur along the western site boundary. It is

considered to form part of the 'clay' deposits which comprise the greatest part of the overburden section in the water well logs.

The Halton Till is generally a clayey silt to silty clay in texture. Locally, it varies to silt and sandy silt in Boreholes GL4 and GL6 respectively. The presence of the coarser textured Halton Till in Borehole GL6 appears to relate to the 'Walnut Hill' morainic feature. The moraine is not visible at Borehole GL4 but the variability noted in the till suggests a possible buried continuation of this feature. The Halton Till differs from adjacent glaciolacustrine units by being relatively more massive and less well laminated (Section 8.4).

Silty fine sand layers between 0.1 and 0.2 m thick occur within the Halton Till at depths of approximately 17 to 18 m in Boreholes GL1 and GL5 and may be continuous between these boreholes. This interval may also be continuous with the silty fine to medium sand layer which occurs between 10 and 15 m in Borehole GL6. These occurrences are identified in the borehole logs and are identified on the cross-sections in Figures 5 and 6. Laminated sections and gradational contacts with the adjacent glaciolacustrine deposits suggest a waterlain origin for much of the Halton Till. This is consistent with the geologic history of the region proposed by Feenstra (1981).

Till thicknesses in GLAL boreholes vary from 1.5 to 15.1 m except at 'Walnut Hill' (Borehole GL6) where the Halton Till and the interbedded sands reached 19.8 m. 'Walnut Hill' is considered to be part of a partially buried moraine which is anomalous with respect to the general stratigraphy at Site

LF-1E. Its influence on the subsurface conditions adjacent to Walnut Hill is not predictable with the present data. Deposits indicative of a moraine were not encountered in other GLAL boreholes, however interpretations of St. Lawrence Seaway Authority borehole records suggest that the Halton Till may be close to the surface at the southwest corner of the site. The 'Walnut Hill' morainic feature was identified in Phase 3B field work (GLAL 1984b) but was not previously identified in the published geologic literature. It is an addition to the features and geologic history described by Feenstra (1981).

4.1.7 UPPER GLACIOLACUSTRINE UNIT

This unit is typically a brown to dark grey silty clay to clayey silt with occasional pebbles and silt laminae. Sandy textures and occasional sand lenses may occur locally. In the southern part of the site (Boreholes GL4 and GL5), up to 4.0 m of the lower portion of the upper glaciolacustrine unit consists of silty fine sand and sandy silt. A sand lens noted in a ditch near the northern site boundary (GLAL 1984b) has distinct upper and lower boundaries and appears to be encapsulated within the clayey glaciolacustrine deposits. A local resident reported that a pond in the central portion of the site filled quickly with water during construction. This may relate to the presence of sand layers such as the occurrence noted above.

The upper glaciolacustrine deposit is usually laminated but may contain massive zones. A subtle colour change occurs from brown to grey brown or grey at depths of 5 to 6 m. The upper 1 to 2 m is intensely weathered and fractured and rarely shows visible laminations. Fracture frequency decreases rapidly

with depth and fractures are infrequent below about 5 m. The deepest evidence of fracturing was noted in Borehole GL2 at a depth of 7.0 m (Section 8.4). Grey carbonate infilling (with a clay-like texture) was observed in many fractures. The upper glaciolacustrine unit ranges in thickness from 9.0 m in Borehole GL1 to 18.1 m in Borehole GL4. It is absent in Borehole GL6 where the Halton Till and associated sand interbeds extend to the surface.

4.1.8 DISCUSSION

Geologic deposits demonstrate relatively more uniformity and predictability beneath the central and northeastern portions of the site where the upper and lower glaciolacustrine units and the Halton Till have a consistently clayey texture. Farther south, the lower part of the upper glaciolacustrine unit is sandy and the Halton Till is silty. To the northwest and southeast, the lower glaciolacustrine unit is absent and the Halton Till directly overlies the lower till which occurs at relatively shallow depths. Immediately east of the site, the Halton Till extends to the surface as a moraine which contains sand layers that may be interconnected with sand encountered in boreholes to the south and west within the Halton Till.

4.2 SITE HYDROGEOLOGY

The Phase 4A field work combines first-hand geologic descriptions and interpretations with the existing data base (primarily water well record and borehole information). Hydrogeologic analyses utilize GLAL borehole geology, water well and borehole records, information obtained from the public, information supplied by researchers in similar hydrogeologic settings, and the experience of Gartner Lee

Associates Limited staff. Descriptions of the hydrostratigraphic units, flow systems, ground water use, and potential contaminant pathways are presented in the following sections.

4.2.1 HYDROSTRATIGRAPHY

Three major hydrostratigraphic units are present at Site LF-1E. These are: (1) a fractured bedrock and associated basal granular aquifer, (2) granular zones or phases within the glaciolacustrine units and the Halton Till, and (3) a confining layer which extends from the surface to the depth of the first significant granular deposit or to bedrock. The confining layer contains up to three hydrostratigraphic subunits which may include (i) the lower till, (ii) the unfractured lower glaciolacustrine unit, the Halton Till, and the upper glaciolacustrine unit, and (iii) the surficial fractured portion of the upper glaciolacustrine unit. Confining layer thicknesses are provided in Figure 7 (in map pocket).

4.2.1.1 Bedrock and basal granular aquifers

The bedrock aquifer is the most important source of water to drilled wells in the study area. GLAL boreholes at three locations encountered dolostone, shale, and shale and gypsum. Numerous bedding planes and occasional small vugs were noted in rock cores obtained during the drilling program. The consistency with which bedrock wells have encountered adequate water supplies within a couple of metres of the bedrock surface suggests that horizontal fracturing is well developed, however the variability in reported pumping rates and drawdowns indicate that the fractures are unevenly distributed. The upper fractured portion of the bedrock is sufficiently permeable to sustain pumping rates (during well development) which range from 0.05 to 0.7 litres per second (L/s) with an

average rate of about 0.5 L/s (Section 8.1). The average hydraulic conductivity of this zone is estimated to be approximately $3x10^{-5}$ m/s based on test pumping data from local water well records and calculation procedures described by Walton (1962) and Ogden (1965). The average porosity is considered to be about 0.01. Details of water quality and quantity in this aquifer are provided in Section 4.2.3.

About half the well records in the study area report granular deposits immediately above the bedrock and water supplies have been developed in these deposits at four locations. Where basal granular deposits are present, they are expected to have good hydraulic connection with the bedrock.

4.2.1.2 Granular zones

The confining layer terminates at granular deposits in 4 of the 6 GLAL boreholes. The lower glaciolacustrine unit contains up to 3 m of fine sand. The Halton Till contains a thin sand layer which may be continuous with sand deposits at Walnut Hill. Several sand layers are interbedded with Halton Till on the 'Walnut Hill' moraine, and the lower part of the upper glaciolacustrine unit is silty and sandy in Boreholes GL4 and GL5. Sand layers and sandy textures tend to be more common in the eastern and southern portions of the site and may be related to the moraine.

4.2.1.3 Confining layer

The confining layer extends from surface to the base of the lower till or to the first significant granular layer which is considered to offer potential for offsite ground water

movement. It ranges from 9.0 to 27.1 m in thickness in the GLAL boreholes located on the site (Figure 7 in map pocket and Table 2) and is characterized by fine-textured materials which have low hydraulic conductivities. The confining layer is considered not to be present at Borehole GL6 ('Walnut Hill') immediately east of the site boundary. It comprises portions of the lower till, the upper and lower glaciolacustrine units, and the Halton Till depending on local stratigraphic conditions. Each of the confining layer subunits is described in the following paragraphs. Table 2 summarizes thicknesses and selected hydrogeologic properties of the confining layer.

The lower till is included as part of the confining layer only at Boreholes GL2 and GL3. At other borehole locations, the confining layer terminates at sand layers which are considered to have potential for offsite ground water movement. The texture of the lower till is a sandy silt to silty sand. Based on textural considerations, the average hydraulic conductivity of the lower till is estimated to be about 1×10^{-8} m/s which is within the range of values provided by Freeze and Cherry (1979) for silt and glacial till. The porosity is considered to be approximately 0.3.

The lower till ranges in thickness from approximately 3 to 9 m in GLAL boreholes and depths to the top of the deposit vary from about 14 to 27 m. Sand layers 0.1 and 1.4 m thick were encountered within the lower till at Boreholes GL1 and GL6 respectively.

Fine-textured silty clays and clayey silts of the upper and lower glaciolacustrine units and the Halton Till are included in the confining layer in Boreholes GL2 and

TABLE 2: SUMMARY OF CONFINING LAYER CHARACTERISTICS

BOREHOLE / PARAMETER	THICKNESS OF CONFINING LAYER SUBUNITS			
	LOWER TILL (m)	UNFRACTURED GLACIOLACUSTRINE UNITS: HALTON TILL (m)	SURFICIAL FRACTURED ZONE (m)	THICKNESS OF CONFINING LAYER (m)
GL1	N/A	11.9	5.0	16.9
GL2	3.7	18.4	5.0	27.1
GL3	3.6+	9.2	5.0	17.8+
GL4	N/A	9.1	5.0	14.1
GL5	N/A	4.0	5.0	9.0
GL6	N/A	N/A	N/A	0
Average hydraulic conductivity m/s	$1x10^{-8}$	$3x10^{-10}$	$1x10^{-8}$	
Average porosity	0.3	0.5	0.0001	

Notes: - N/A - Not applicable

- Porosity values in the unfractured materials reflect intergranular porosity. Additional fracture porosity is present in the fractured zone. The fractures are accompanied by increased hydraulic conductivities with the result that ground water can potentially move more rapidly in fractures. Fractured zone porosity is effective porosity as reported by Desaulniers (1982).

and GL3. In Boreholes GL4 and GL5, the confining layer terminates in silty fine sands which occur near the base of the upper glaciolacustrine unit. In Borehole GL5, it terminates at the Halton Till. In Borehole GL6 ('Walnut Hill'), granular deposits occur very near to the surface and the confining layer is considered to be absent.

Onsite hydraulic conductivities for Halton Till and unfractured glaciolacustrine portions of the confining layer are considered to be similar to values reported by Desaulniers et al. (1981) in fine-textured deposits near Wainfleet. These values range from 1.1×10^{-10} to 8.2×10^{-10} m/s for laboratory tests and from 1.3×10^{-10} to 7.9×10^{-10} m/s for in situ tests. (The overall geometric mean is approximately 3×10^{-10} m/s). Porosities ranged from 0.34 to 0.60 at Wainfleet and the approximate average of this range (0.5) is used in estimating flow rates in Section 4.2.2. Laboratory and field testing of similar fine-textured glaciolacustrine deposits near Lewiston, New York yielded a range of hydraulic conductivities from 1.4×10^{-10} to 8.7×10^{-10} m/s over depths from 4.7 to 10.0 m (Wehran Engineering P.C. 1983). None of the water wells for which Ministry of the Environment records are available in the study area terminates in the confining layer.

The upper 1 to 2 m (approximately) of the confining layer is most severely fractured, however fracture frequency declines rapidly with depth as the fractures become more tightly closed and fewer. Based on the borehole logs, it is estimated that fracturing is generally limited to depths of about 5 m and while occasional, individual fractures are noted at greater depths, they are rare. The deepest fracture noted on the site occurred at 7.0 m in Borehole GL2.

Freeze and Cherry (1979) note that deposits of clayey or silty till and glaciolacustrine deposits in southern Ontario contain networks of hairline fractures which are essentially vertical and which are responsible for hydraulic conductivities one to three orders of magnitude greater than in unfractured materials. Based on this observation, the fractured zone is assigned a hydraulic conductivity of 1×10^{-8} m/s which is approximately two orders of magnitude greater than the underlying fractured deposits.

The surficial fractured zone is included within the confining layer because it is part of the upper glaciolacustrine unit and is clayey and silty in texture. While the higher hydraulic conductivity is applied to a fractured zone which is about 5 m thick, this fracturing is considered to be significant only in the upper 1 to 2 m, as deeper fractures are more tightly closed and fewer in number.

Desaulniers (1982) reports an effective fracture porosity of 0.0001 in glaciolacustrine deposits in Lambton County. These deposits are considered similar to materials at this site and this porosity value is considered to be applicable here.

Two shallow or dug wells are reported on the site and a third is located immediately east of the site on 'Walnut Hill'. The offsite well is 2.4 m deep and probaoly obtains water from shallow sands which are part of the morainic deposits. The depths of the onsite wells are not known, however the ground water is expected to originate in part from fractures and in part from sand laminations within the confining layer. Local water supply is discussed in Section 4.2.3.

4.2.1.4 Discussion

Sand layers associated with the 'Walnut Hill' morainic feature appear to interfinger with adjacent upper glaciolacustrine and Halton Till clayey deposits. As such, these deposits may contain sand layers and may therefore be unsuitable for inclusion in the confining layer.

4.2.2 GROUND WATER FLOW REGIME

Infiltration is the source of ground water and differences in hydraulic head provide the driving force for ground water flow systems. At the site, shallow lateral flow is considered to exist in the saturated portion of the fractured zone. A vertical flow system slowly transports small amounts of ground water down and through the confining layer and a mainly lateral flow system occurs within the upper bedrock and associated granular deposits. The site is located in an area where hydraulic gradients in the confining layer are downward. This condition is indicated by a water table which is close to the surface and by water levels in the underlying aquifer which are several metres below ground. Flow systems are discussed below and estimates of flow rates are provided for comparative purposes.

The water table occurs in the fractured zone and its shape is a reflection of topography. Fracturing and ground water flow diminish rapidly to the base of this zone which extends to a depth of about 5 m on the site. Shallow flow is most active in the upper 1 to 2 m where fracturing is most common and where fracture permeability is best developed. Ground water movement is essentially lateral and rates and directions of flow are dependent on elevation differences in

the water table. Desaulniers et al. (1981) reports that ground waters below depths of 3 to 4 m in fine-textured deposits near Wainfleet were recharged prior to the early 1950s based on tritium analyses. The average lateral flow rate in the fractured zone is about 10 m per year based on an approximate gradient of 0.003, an average hydraulic conductivity of 1×10^{-8} m/s and an average effective porosity of 0.0001. Sample calculations of flow rate employing Darcy's Law are shown in Section 8.5. Fracture flow predictions may be unrealistically large if the rates are interpreted as 'straight line' pathways because fractures may be complex and interconnections indirect or poorly developed. The quantity of flow in the shallow system is greatest when the water table is closest to ground level and the saturated zone is thickest. Flow rates and quantities are much less in the unfractured portion of the confining layer.

Ground water gradients in the confining layer are downward, however flow rates and amounts of flow are expected to be very small. The average downward gradient in wells on the site and adjacent to the site (based on static water levels reported at the time of well construction) is about 0.3. In calculating gradients, the water table was considered to be at ground level to provide a maximum head differential or driving force across the confining layer. Hydraulic gradients measured by Desaulniers et al. (1981) near Wainfleet were downward and ranged between 0.02 and 0.17 over depths to approximately 30 m in fine textured deposits. Confining layer thicknesses range from zero near 'Walnut Hill' (Borehole GL6) to about 27 m in the northeast part of the site.

Table 3 presents a summary of flow rates in the hydrostratigraphic subunits which comprise the confining layer. A

methodology for estimating flow rates in the confining layer is given by Freeze and Cherry (1979) and is summarized in Section 8.5 along with a sample calculation.

TABLE 3: ESTIMATED VERTICAL FLOW RATES IN THE CONFINING LAYER

BOREHOLE	CONFINING LAYER FLOW RATES (m/s)		
	FRACTURED ZONE	UNFRACTURED GLACIOLACUSTRINE AND HALTON TILL	LOWER TILL (m/s)
GL1	1×10^{-6}	3×10^{-10}	N/A
GL2	1×10^{-6}	3×10^{-10}	4×10^{-10}
GL3	2×10^{-6}	3×10^{-10}	6×10^{-10}
GL4	1×10^{-6}	3×10^{-10}	N/A
GL5	2×10^{-6}	4×10^{-10}	N/A

Notes: N/A = not applicable

Average hydraulic conductivity and porosity estimates are provided along with thicknesses for the confining layer subunits in Table 2.

Multiply by 3.15×10^{7} for flow rates in metres per year.

Inspection of Table 3 indicates that estimated vertical ground water velocities in the fractured zone are about four orders of magnitude greater than in the remainder of the

confining layer and that the unfractured confining layer is the dominant unit controlling ground water flow. A more accurate assessment of ground water flow rates through the confining layer using advection and diffusion calculations is contained in Appendix A of the report entitled "Site Selection Process; Phase 4A, Selection of Preferred Site(s), Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985). Desaulniers et al. (1981) concluded that pore waters at depth in fine-textured deposits near Wainfleet (and other southern Ontario locations) originated approximately 8700 to 9800 years ago.

Where sand and gravel occur in hydraulic connection with the bedrock, the flow system in the sand and gravel can be expected to be similar to that of the bedrock. Ground water movement in the bedrock occurs primarily within the upper few metres where fractures are best developed and where they have been enhanced through solution. Most bedrock wells obtain water within the upper 2 m and the zone of major flow in the bedrock is considered to occur within the upper 5 m. Vugs and fractures were noted in cored samples of the bedrock. The general direction of ground water flow appears to be northward based on static water level elevations derived from water well records for the study area (Section 8.1). The average lateral ground water flow rate through the upper bedrock is estimated to be about 3×10^{-6} m/s (100 metres per year) based on an average hydraulic conductivity of 3×10^{-5} m/s, a gradient of 0.001, and a porosity of 0.01. The gradient is estimated from the water well summary (Section 8.1). As indicated previously, fracture flow rates may be unrealistically large if they are interpreted over 'straight-line' distances since fracture

connections are usually complex and interconnections may be indirect or poorly developed.

4.2.3 GROUND WATER USE

Water use information is based on water well record data and on data collected from residents and landowners on the site and on adjacent properties.

4.2.3.1 Availability

Water supplies for domestic, stock, and general agricultural purposes are obtained primarily from cisterns, drilled wells, ponds, and occasionally from dug wells. Some cisterns are supplied by rainwater, some are supplemented by trucked water during dry periods and some are supplied with trucked water on a full-time basis. Water use information is summarized in Figure 8 (in map pocket) and is supported by "Walk and Talk" summaries in Table 6 (Section 8.3).

Based on water well records, the bedrock and basal sand and gravel deposits are sources of supply to drilled wells in the study area. Yields from the bedrock and from the sand and gravel do not appear to differ substantially. Test pumping rates during development range up to 0.8 litres per second (L/s) and drawdowns in about three quarters of the cases are less than 3 m. Drilling contractors most frequently recommend pumping rates in the range of 0.1 to 0.8 L/s with pump settings between 9 and 24 m. In most cases, adequate supplies are obtained from the bedrock within the upper 2 m, though penetration depths up to 13 m are reported. The locations of wells which obtain water from the sand and gravel deposits follow no apparent pattern and in several cases the driller has

reported sand and gravel but has cased through it to obtain supplies from bedrock.

Five wells (two dug or bored and three drilled) were reported on the site during field information surveys (Figure 8) in addition to those on on record with the Ministry of the Environment. These wells are used for domestic, stock and general agricultural purposes. The two dug or bored wells are located at northern and central locations on the site but no depth or yield information is available for either well. The supply from one of the dug wells is reportedly augmented with trucked water a couple of times per year. A dug well also exists immediately beyond the eastern site boundary on 'Walnut Hill'. It is approximately 2.4 m (8 ft) deep and is considered to obtain water from shallow sand deposits associated with the moraine at this location.

Cisterns are the most common source of water supply on the site and in the study area. Most cisterns 'dry up' periodically during periods of low rainfall and several are maintained with trucked water. Dugouts and off-stream ponds are occasionally used for stock and agricultural purposes. Many dugouts likely penetrate the water table although some may rely on surface runoff. Water use distribution in the study area based on 43 responses is as follows: 30 reported one or more cisterns, 17 reported drilled wells, 3 reported dug/bored wells, and 18 reported one or more ponds.

4.2.3.2 Quality

Ground water quality from the bedrock and from deep sand and gravel deposits near the bedrock contact is reportedly 'fresh' in about three quarters of wells in the study area and

'sulphurous' in the remainder. 'Sulphurous' ground water is reported throughout the study area but appears to be more frequent in the north. One well (#32, Table 6) has not been used for reasons of poor water quality and other drilled wells are used for limited purposes because of marginal quality.

4.2.4 POTENTIAL CONTAMINANT PATHWAYS

In general, there are two hydrogeologic pathways by which contaminants could potentially leave this site; these are (1) natural pathways along ground water flow systems, and (2) manmade pathways which follow such structures as abandoned and unplugged wells and tile drains. The natural pathways would tend to retard ground water movement because of the low hydraulic conductivity of the confining layer and are discussed under Site Hydrogeology (4.2.1) and Ground Water Flow Regime (4.2.2).

Efforts have been made to identify and locate man-made structures such as water wells, gas wells, tile drainage systems and excavations which may be located on site. These structures could act as pathways along which contaminants could potentially leave the site. For example, improperly sealed and abandoned wells which penetrate the confining layer could provide an off site pathway for surface water and shallow ground water.

Three drilled and two dug/bored wells were identified on the site through the field interviews. Four of the wells are believed to be in active use. Well locations are shown on Figure 8 and the three drilled wells probably penetrate the confining layer. Gas wells are common in the area and

ten wells including active and abandoned wells were reported on the site; five of these were reported by local residents and are noted along with water use comments in Table 6 (Section 8.3).

Excavations are believed to be limited to the immediate vicinity of buildings on the site and no extensive corridors of permeable backfill materials or tile drains were identified from the interview sheets.

5.0 GEOTECHNICAL CONSIDERATIONS

This section provides a preliminary assessment of Site LF-1E from a soils engineering viewpoint. The geologic setting is described in detail in Section 4.0 of this report.

The geologic data base has been supplemented by standard split spoon tests at 1.5 m intervals in each of the GLAL boreholes. The standard penetration (N) values have been used as a guide in estimating the relative density and consistency of the various geologic units. Shear strengths noted here are estimated from blow-count shear-strength relationships obtained from other studies in similar materials in the Niagara Peninsula. Moisture contents are presented together with N values on the geologic logs (Section 8.4).

A desiccated crust 3 to 8 m thick is associated with the surficial portion of the upper glaciolacustrine deposit over the site except in the vicinity of Borehole GL6. It has a

generally very stiff to hard consistency based on N values that range between 14 and 36 (blows per 0.3 m) and undrained shear strengths which range from approximately 100 to greater than 200 kPa (kilopascals). Moisture contents in the desiccated crust are generally in the range of 18 to 24% indicating the material is drier than the plastic limit to about the plastic limit.

The deeper portion of the upper glaciolacustrine deposit below the desiccated crust will most influence site development. This zone has a firm to stiff consistency with N values typically in the range of 4 to 11 except in Borehole GL2 where the deposits have a very stiff consistency (with N values of 16 to 19). The former values correspond to undrained shear strengths of 20 to 50 kPa with local zones in Borehole GL2 approaching 150 kPa. The in situ moisture contents are between 18 and 28% and generally indicate wetter than plastic limit conditions. In the southeastern portion of the site (Borehole GL4), the upper glaciolacustrine deposits consist of loose to compact silty fine sand. These deposits have N values of 3 to 15 and in situ moisture contents of 18 to 25%.

Except at Borehole GL4, and GL6, the Halton Till exhibits a firm to hard consistency with N values between 6 and 57. In general, Boreholes GL2 and GL3 have lower N values, and Boreholes GL2, GL3, and GL4 have higher N values. Corresponding undrained shear strengths range from about 35 kPa to greater than 200 kPa and the in situ moisture contents range between 8 and 22%. The Halton Till at Boreholes GL4 and GL6 is dense to very dense with N values up to 96. There are

beds of dense sand within the till and in situ moisture contents range from 8 to 17%.

The lower glaciolacustrine deposit varies in consistency from stiff to hard with N values of 8 to 56. In situ moisture contents range from 18 to 40%.

The lower till which overlies the bedrock is dense to very dense with N values typically greater than 50. In situ moisture contents are generally less than 10%.

Preliminary assessments based on data from the GLAL boreholes indicate that geotechnical conditions within Site LF-1E will influence development from a soils engineering point of view. However, it is considered that sub-surface aspects can be handled with proper design and standard techniques within the geotechnical guidelines provided below.

As a general guide, temporary excavations in areas of the site represented by Boreholes GL2 and GL3 can be extended to 10 m below ground surface at 2:1 side slopes with no significant problems. In order to safeguard against heave, temporary excavations in other parts of the site as represented by Boreholes GL1, GL4, and GL5 should be limited to about 5 m at 2:1 side slopes. Excavations that extend deeper into the softer clayey deposits should be investigated in greater detail from stress relief and stability perspectives. Where saturated sand and silty sand zones in the upper glaciolacustrine unit are intersected during excavation, ground water control will be required.

Temporary excavations into the Halton Till (near Borehole GL6) can be extended 10 m to 15 m below ground surface at 2:1 side slopes. Water-bearing sand seams will be intersected and ground water control will be necessary.

Treated waste residues could be placed to thicknesses of about 1.5 times the depth of the cells (based on a waste density of 1.35 tonnes per cubic metre) without creating a surcharge load. Provided there is no surcharge load within the cell base, settlement will be minimal. As well, no problems related to bearing pressure are anticipated. Greater fill thicknesses might be possible but would require detailed investigations from settlement and stability perspectives. For the above-ground option, fills could be constructed to heights of approximately 15 m above ground level with waste slopes of 3:1 based on the current data. For fills of this height placed on the clayey sub-soils, some settlement of the subsoils would be likely. This aspect would require detailed investigation.

Over most of the site there is a desiccated crust where the clays are generally very stiff to hard in consistency. The allowable bearing pressure in the crust is generally sufficient for light and medium weight structures with shallow strip or conventional pad footings. As a guide, an allowable bearing pressure of 150 kPa can be adopted for footings founded in the upper 1.5 m of the desiccated crust. Provided that most of the applied foundation stresses are dissipated within the crust, settlement should be within tolerable limits.

For heavy structures it will likely be necessary to

transfer loads to either the lower till or to locally hard zones within the Halton Till where adequate bearing pressure is available. This aspect will require detailed foundation investigations during Phase 4B work on the preferred site. In the vicinity of Borehole GL6, the allowable bearing pressures are likely adequate for structures provided proper foundation design is carried out.

The clayey subsoils on the site are workable. However due to their 'wet' and 'sticky' nature they will be a nuisance from a materials handling and trafficability perspective. The situation will be aggravated during wet weather conditions.

6.0 SUMMARY

The site is located on the Haldimand Clay Plain within the corporate limits of the City of Niagara Falls. It is situated at the contact of the Guelph and Salina bedrock formations and is underlain by dolostones and shales. The overburden consists of a discontinuous basal sand and gravel unit, a lower till, a lower glaciolacustrine unit, the Halton Till, and an upper glaciolacustrine unit. Depths to bedrock vary between about 25 and 35 m. The glaciolacustrine and till units range in texture from silt and clay to sand. A partially buried moraine ('Walnut Hill') lies immediately to the east of the site and consists of Halton Till and interbedded sands. The moraine is considered anomalous with regard to geologic conditions over most of the site. Sand associated with the moraine feature appears to interfinger with the adjacent glaciolacustrine deposits.

Major hydrostratigraphic units in the study area include: (1) the bedrock and basal granular aquifers, (2) granular zones within the glaciolacustrine units and the Halton Till, and (3) the confining layer. The bedrock and basal granular aquifers are regional sources of municipal, domestic, agricultural, and industrial water supply and provide domestic and farm supplies in the study area. Water quality ranges from 'fresh' to 'sulphurous'. The confining layer consists of three glaciolacustrine units and the Halton Till, and (3) the surficial fractured portion of the upper glaciolacustrine unit. The surficial fractured portion of the confining layer is about 5 m thick. Ground water flow in the fractured zone is essentially lateral in response to water table gradients. Average rates of lateral flow are estimated at about 10 m per year. Average vertical flow through the unfractured confining layer is in the range of 0.008 m per year for the silty and clayey deposits and about 0.01 m per year in the lower till. Natural flow systems in the confining layer are generally sluggish and flow rates and quantities are exceedingly small, however the confining layer is considered to be variable and unpredictable. Interfingering of sand layers, associated with Walnut Hill may act as natural pathways for off site ground water movement. Ground water flow in the bedrock aquifer is considered to be primarily lateral at rates in the range of 100 m per year. Man-made potential conduits to the underlying aquifer on the site appear to be limited to water wells and oil and gas wells.

Preliminary geotechnical assessments indicate there is a desiccated crust over most of the site. This crust is up to 8 m thick and has undrained shear strengths in the range of 100 to greater than 200 kPa. Based on the available data,

temporary excavations to about 10 m at 2:1 side slopes can be undertaken with no problems in the northern portion of the site. In deposits similar to those at 'Walnut Hill', excavations between 10 and 15 m are expected to be stable but will require ground water control. Over most of the remainder of the site, excavations should be limited to about 5 m. Treated waste residues may be placed to thicknesses of about 1.5 times cell depth below grade. For the above ground option, fills could be constructed to heights of about 15 m above ground surface before bearing pressure failures become a concern. Deeper excavations or increased thicknesses of treated waste residues should be preceded by more detailed geotechnical investigations. The desiccated crust provides adequate bearing pressure for light and medium weight structures provided proper engineering design is carried out. For heavy structures it will likely be necessary to transfer loads to the lower till or other competent strata.

The clayey subsoils on the site are workable. However, due to their 'wet' and 'sticky' nature, they will be a nuisance from a materials handling and trafficability perspective. The situation will be aggravated during wet weather conditions.

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8.0 SUPPORTING INFORMATION

8.1 SUMMARY OF WATER WELL DATA (TABLE 4)

8.2 SUMMARY OF OIL AND GAS WELL DATA (TABLE 5)

8.3 SUMMARY OF SITE INTERVIEW (WALK AND TALK) DATA (TABLE 6)

8.4 BOREHOLE LOGS

8.5 SUPPORTING CALCULATIONS AND METHODS

8.6 GLOSSARY OF SELECTED TERMS

8.7 DETAILED FIELD METHODS

8.1 SUMMARY OF WATER WELL DATA

Water well locations are shown in Figure 4 (in map pocket).

Copies of original Water Well Records obtained from the Ontario Ministry of the Environment (MOE) were used for the following data summary and are on file.

Measurements, dimensions, and quantities on the Water Well Records are in Imperial units but are presented in metric units in the following summary.

Water well locations were plotted on 1:10 000 scale maps for this project and elevations were re-estimated, based on the more accurate contours on these maps. Well elevations are above sea level (ASL) and are estimated to the nearest metre.

Well records are arranged in numerical order.

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-1E

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
616	WARNER, E. B.F. CON., LOT 2, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	180	NOV 1960	15.9	20.4	FRESH	18.9	8.5	8.5	0.8	DOMESTIC	0.0	14.9	BLUE CLAY
												14.9	18.9	GRAVEL
												18.9	20.4	LIMESTONE
618	WARNER,A B.F. CON., LOT 3, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	179	JAN 1960	12.7	21.3	FRESH	19.8	9.8	11.6	0.8	DOMESTIC STOCK	0.0	7.3	RED CLAY
												7.3	12.2	HARDPAN
												12.2	19.8	BLUE CLAY
												19.8	21.3	LIMESTONE
624	LUSTY, W CON. 1, LOT 1, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	179	MAY 1954	15.9	20.4	SULPHUROUS	20.4	4	9.1	0.8	DOMESTIC	0.0	0.3	SANDY LOAM
												0.3	19.5	BLUE CLAY
												19.5	19.8	GRAVEL, LITTLE WATER
												19.8	20.4	LIMESTONE ROCK
												20.4	--	LIMESTONE ROCK, WATER
625	CRUICKSHANK, E. CON. 1, LOT 4, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	179	MAY 1956	15.2	17.1	FRESH	14.6	5.8	7.3	0.6	DOMESTIC STOCK	0.0	0.6	TOPSOIL
												0.6	5.2	BROWN CLAY
												5.2	14.3	BLUE CLAY
												14.3	17.7	BROWN ROCK

[redacted] Cartne[redacted] Ass[redacted]es L[redacted]d [redacted]

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-1E

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
631	WETZEL, G.E. CON. 2 LOT 2 CITY OF NIAGARA FALLS (FORMERLY CROWLAND TWP.)	179	NOV 1963	16.8	24.4	FRESH	24.4	4.6	24.4	0.1	DOMESTIC	0.0	3.0	HARD BROWN CLAY
												3.0	20.4	SOFT BROWN CLAY
												20.4	24.2	SANDY CLAY
												24.2	24.4	FINE COARSE GRAVEL
												24.4	25.6	LIMESTONE
632	GYURSCI, J CON. 2, LOT 10 CITY OF WELLAND (FORMERLY CROWLAND TWP.)	183	SEP 1959	12.7	24.4	SULPHUROUS	24.4	7.3	8.2	1.4	STOCK	0.0	0.3	TOPSOIL
												0.3	4.9	BROWN CLAY
												4.9	18.3	BLUE CLAY
												18.3	22.2	CLAY AND PEBBLES
												22.2	24.4	GRAVEL
												24.4	27.4	BLUE ROCK
638	COOKS MILLS SCHOOL CON. 3, LOT 1 CITY OF NIAGARA FALLS (FORMERLY CROWLAND TWP.)	177	SEP 1949	10.2	39.6	FRESH	NA	8.2	35.1	0.8	PUBLIC	0.0	3.0	HARD CLAY
												3.0	25.3	BLUE CLAY
												25.3	27.4	BLUE CLAY, SMALL STONES
												27.4	39.3	BLUE CLAY
												39.3	40.2	LIMESTONE, WATER
639	WATTS, J CON. 3, LOT 2 CITY OF NIAGARA FALLS (FORMERLY CROWLAND TWP.)	178	JUL 1949	15.9	21.9	FRESH	21.9	6.1	6.1	0.3	DOMESTIC	0.0	9.1	HEAVY RED CLAY
												9.1	21.9	QUICK SAND
												21.9		GRAVEL
640	MAJOROS, J. CON. 3, LOT 9, CITY OF NIAGARA FALLS (FORMERLY CROWLAND TWP.)	182	MAY 1964	15.9	25.9	FRESH	25.9	7	9.1	0.8	DOMESTIC STOCK	0.0	16.8	BROWN CLAY
												16.8	24.3	RED PACKED GRAVEL
												24.3	25.9	WATER GRAVEL
645	BRADLEY, C. CON. 4, LOT 2 CITY OF NIAGARA FALLS (FORMERLY CROWLAND TWP.)	179	NOV 1964	12.7	27.4	FRESH	26.5	4.9	15.2	0.6	DOMESTIC STOCK	0.0	12.2	RED CLAY
												12.2	18.3	BLUE CLAY
												18.3	22.6	HARD PAN
												22.6	26.5	SAND AND FINE GRAVEL
												26.5	27.4	SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-1E

Sheet 3 of 5

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
646	MSHENAKAS, A CON. 4, LOT 6 CITY OF NIAGARA FALLS (FORMERLY CROWLAND TWP.)	182	FEB 1961	14.3	23.5	SULPHUROUS	23.5	6.1	24.4	0.2	DOMESTIC	0.0	6.7	HARD CLAY
												6.7	12.5	SOFT CLAY
												12.5	20.1	HARD CLAY
												20.1	22.2	SOFT CLAY (SANDY)
												22.2	23.5	HARD PAN
												23.5	26.8	LIMESTONE ROCK
647	W.L. PEARSON & SONS CON. 4, LOT 8 CITY OF NIAGARA FALLS (FORMERLY CROWLAND TWP.)	182	NOV 1952	11.4	24.7	FRESH	24.4	7.6	NA		DOMESTIC	0.0	6.1	HARD RED CLAY
												6.1	20.7	SOFT GRAVELLY RED CLAY
												20.7	23.8	FINE GREY SAND
												23.8	24.4	SOFT RED CLAY
												24.4	25.3	GREY LIMESTONE
648	BRANDSTATTER, H CON. 4, LOT 11, CITY OF WELLAND (FORMERLY CROWLAND TWP.)	181	APR 1962	15.9	30.5	FRESH	30.5	4.3	4.3	1.2	DOMESTIC	0.0	23.2	CLAY
												23.2	24.4	GRAVEL AND BOULDERS
												24.4	25.6	COARSE GRAVEL (NO WATER)
												25.6	29.9	CLAY AND GRAVEL
												29.9	30.5	SAND
650	CLARKE, V. CON. 5, LOT 8 CITY OF NIAGARA FALLS (FORMERLY CROWLAND TWP.)	186	JUN 1964	15.9	27.7	FRESH	28	11	11	1.2	DOMESTIC	0.0	3.7	CLAY
												3.7	9.1	QUICK SAND AND CLAY
												9.1	13.7	STONES AND SAND
												13.7	27.4	HARD PACKED SAND
												27.4	27.7	WATER SAND

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-1E

Sheet 4 of 5

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2380	PRINC, L. CON. 1, LOT 7 CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	178	NOV 1968	15.9	30.2	SULPHUROUS	22.9	7.6	9.1	0.8	DOMESTIC STOCK	0.0	7.7	BROWN CLAY
												7.7	19.8	BLUE CLAY
												19.8	21.0	BLUE CLAY & STONES
												21.0	22.9	BLUE CLAY & GRAVEL
												22.9	30.5	GREY NIAGARA ROCK
2494	LAFRENIERE, L. CON. 2, LOT 2 CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	178	DEC 1969	15.2	20.1	FRESH	20.1	10.7	13.7	0.6	DOMESTIC	0.0	16.7	BROWN CLAY, PACKED
												16.7	18.9	BLUE CLAY, GRAVEL, HARD
												18.9	19.8	GREY HARDPAN, STONES, HARD
												19.8	20.1	GREY LIMESTONE, LAYERED
2513	BIGGAR, K B.F.CON., LOT 6, CITY OF NIAGARA FALLS (FORMERLY CROWLAND TWP.)	178	APR 1970	15.9	36.6 47.2	SULPHUROUS	34.7	NA	36.6	0.4	STOCK	0.0	6.7	BROWN CLAY, PACKED
												6.7	20.4	REDDISH CLAY, SOFT (GAS)
												20.4	34.4	GREY CLAY, GRAVEL, HARD (GAS)
												34.4	47.9	GREY NIAGARA ROCK, LAYERED
2521	MATTHEWS, C.G. CON. 4, LOT 18, CITY OF WELLAND (FORMERLY CROWLAND TWP.)	181	JUN 1970	15.9	31.4	NA	31.4	13.1	14.6	0.8	STOCK	0.0	9.8	BROWN CLAY, SMALL STONES, PACKED
												9.8	25.9	REDDISH CLAY, SOFT
												25.9	30.5	RED CLAY, STONES, PACKED
												30.5	31.4	GREY SHALE, LAYERED
2522	WILLIAMS, T CON. 4, LOT 7, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	182	JUN 1970	15.9	24.1	FRESH	23.8	8.8	9.1	0.8	STOCK	0.0	10.7	BROWN CLAY, PACKED
												10.7	23.2	RED CLAY, SANDY, SOFT
												23.2	23.5	GREY CLAY, GRAVEL, PACKED
												23.5	23.8	GREY SHALE, LAYERED
												23.8	24.4	GREY LIMESTONE, LAYERED
2564	TAYLOR, W. CON. 7, LOT 5, CITY OF NIAGARA FALLS, (FORMERLY WILLOUGHBY TWP.)	175	SEP 1970	15.9	18.9	FRESH	18.9	3.7	5.5	4.6	DOMESTIC STOCK	0.0	11.6	BROWN AND RED CLAY
												11.6	13.4	GREY CLAY
												13.4	15.8	BROWN AND RED CLAY
												15.8	18.9	DIRTY GRAVEL
												18.9	19.2	SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-1E

Sheet 5 of 5

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2921	MANNELL, D CON, 1, LOT 7 CITY OF NIAGARA FALLS (FORMERLY CROWLAND TWP.)	178	JUN 1982	15.9	37.8	MINERAL	36.7	6.1	16.8	1.5	STOCK	0.0	21.9	CLAY
												21.9	36.3	BROWN CLAY AND STONES AND BOULDERS
												36.3	37.8	ROCK

8.2 SUMMARY OF OIL AND GAS WELL DATA

Oil and gas well locations are shown in Figure 4 (in map pocket).

Copies of original oil and gas well records were obtained from the Ministry of Natural Resources (MNR) office in London, Ontario provided locations of abandoned oil and gas wells. These wells are numbered 1 to 36 in Figure 4. Wells 37-47 were noted in discussions with local residents. There is no information available (aside from locations) for these wells.

Imperial units are used in the original well logs and these have been changed to metric units in the summary. Where ground elevations are supplied, they have been verified using contours on the 1:10 000 base map.

Where no elevations were supplied, elevations were estimated from the base maps. All elevations are shown to the nearest metre.

Copies of oil and gas well information are on file.

TABLE 5, SUMMARY OF OIL & GAS WELL DATA

Site: LF-1E

Sheet 1 of 1

WELL BOREHOLE No.	LOCATION	GROUND ELEVATION (m ASL)	FROM (m)	TO (m)	MATERIALS DESCRIPTION	COMMENTS
531	CON. 3, LOT 5 CITY OF NIAGARA FALLS (Prev. CROWLAND TWP.)	182	0.0 24.4	24.4 142.3	OVERBURDEN BEDROCK	GAS PRODUCER
731	CON. 3, LOT 7 CITY OF NIAGARA FALLS (Prev. CROWLAND TWP.)	183	0.0 *24.1	*24.1 189.6	UNKNOWN BEDROCK	GAS PRODUCER (ABANDONED) FIRST CASING SET AT 24.1m (CONSUMERS 639)
741	CON. 4, LOT 7 CITY OF NIAGARA FALLS (Prev. CROWLAND TWP.)	181	0.0 *25.6	*25.6 192.0	UNKNOWN BEDROCK	GAS PRODUCER (ABANDONED) FIRST CASING SET AT 25.6m (CONSUMERS 662)
831	CON. 3, LOT 8 CITY OF NIAGARA FALLS (Prev. CROWLAND TWP.)	184	0.0 *40.8	*40.8 186.5	UNKNOWN BEDROCK	GAS PRODUCER (ABANDONED) FIRST CASING SET AT 40.8m (CONSUMERS 638)
851	CON. 5, LOT 8 CITY OF NIAGARA FALLS (Prev. CROWLAND TWP.)	184	--	--	NO LOG	GAS PRODUCER (ABANDONED) (CONSUMERS 840)
1-36						LOCATIONS IN FIGURE 4
37-47						LOCATIONS IN FIGURE 4

NOTES: * - Designates estimated or approximate depth.

37-47 no data available, locations from field interviews.(see Table 6, no's 7, 13, 14, 16, 40 and 42)

1-36 no data available, locations obtained from Ministry of Natural Resources, Petroleum Resources Maps F-17 (NTS REFERENCE, 30M/3 EAST) AND E17 (NTS REFERENCE, 30L/14 EAST WELLAND) (Effective Dates, February 1984).

Local sources indicate that wells #16 and 17 are south of Schisler Road in Con. 4, Lots 6 and 5 respectively, in contrast to the MNR source map which shows them in Con. 3, Lots 6 and 5 respectively.

8.3 SUMMARY OF SITE INTERVIEW (WALK AND TALK) DATA

Water use data from Ecologistics Limited's field interview (Walk and Talk) forms is presented in Figure 8 (in map pocket). Water use data were collected from residents on the site and on adjacent properties.

Water use data were augmented with information collected by Gartner Lee Associates Limited staff during discussions with local interest groups and individuals.

Deeper drilled wells are considered to terminate in bedrock where supporting evidence is available.

Although most of the information was provided in Imperial units, it has been converted to metric units for uniformity with the remainder of the report.

Interview numbers are related to identifications assigned by Ecologistics Limited during the collection of these data.

A copy of the water resources questionnaire form is attached at the end of this section.

Copies of the interview forms are on file.

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site LF-1E Sheet 1 of 21

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored well(s)	Cistern	Remarks
1	Mr. Ken Biggar	6 City of Niagara Falls (Formerly Crowland TWP.)	BF	13-2	✓		✓	Cistern supplies household Drilled well (MOE well 2513) -47.5m (156 ft.) deep -supplies livestock -water quality sulphurous
2	Mr. Raffaele Butera	8 City of Niagara Falls (Formerly Crowland TWP.)	2	120-2	✓			Drilled well (no MOE record) 27.4m (90 ft.) deep -supplies household and live-stock -water quality soft, good for drinking -no shortage of supply
3	Mr. & Mrs. John Taylor	7 City of Niagara Falls (Formerly Crowland TWP.)	2	111-1		✓		Dug/Bored well (no MOE record) -supplies household -water quality,hard sulphurous -goes dry sometimes -truck in water couple times per year Pond on property (see Number 66)
4	Mr. A. Delvecchio	7 City of Niagara Falls (Formerly Crowland TWP.)	1	267-1				No known water supply on property vacant land

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
5	Mr. Chas Warner	3 City of Niagara Falls (Formerly Crowland TWP.)	2	48-2	✓		✓	Cistern supplies household -rainwater -goes dry 12 times per year Drilled well (no MOE record) -29.0m (95 ft.) deep -water level 7.6m (25 ft.) from surface -supplies livestock -water quality sulphurous
6	Mr. J. Marjoros	10 City of Niagara Falls (Formerly Crowland TWP.)	2	29.2	✓		✓	Cistern supplies household -water trucked in Drilled well (MOE well 632) -29.0m (95 ft.)deep -supplies livestock -water quality hard sulphurous
7	Mr. J. Marjoros	9 City of Niagara Falls (Formerly Crowland TWP.)	3	29-2	✓			Drilled well (MOE well 640) -25.9m (85 ft.)deep -supplies household 2 abandoned gas wells, well #'s 10 and 47 in Figure 4

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored well(s)	Cistern	Remarks
8	Mr. J. Marjoros	8	2	29-2	(✓)			Abandoned well (no MOE record) - unknown well type
		City of Niagara Falls (Formerly Crowland TWP.)						
9	Mr. Joseph Ferete	7	2	117-2			✓✓✓	Cistern for household use -water hauled from town Cisterns (2) for livestock use -water hauled from town
		City of Niagara Falls (Formerly Crowland TWP.						
10	Mr. David Underhill	7	2	116-2	✓		✓✓	Cistern supplies household -filled monthly with trucked in water Bottled water for household Cistern supplies livestock -rainwater Drilled well (no MOE record) -27.4m (90 ft.)deep -supplies livestock -water quality, hard sulphurous Pond supplies livestock -7.6, (25 ft.) deep Gas well in use , well #9 in Figure 4
		City of Niagara Falls (Formerly Crowland TWP.)						

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site LF-1E Sheet 4 of 21

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
11	Mr. Walter G. Kretz	6 City of Niagara Falls (Formerly Crowland TWP.)	2	9-2			✓	Cistern supplies household and livestock -water quality soft, high iron content Pond on property -spring fed Gas well on property, well #3 in Figure 4
12	Mr. George Watson & Ms. Isabelle Watson	5 City of Niagara Falls (Formerly Crowland TWP.)	2	64-1		✓		Dug/Bored well (no MOE record) -supplies household Ponds on property used for fish -rainwater fed (see Number 67)
13	Mrs. Silverthorn	5 City of Niagara Falls (Formerly Crowland TWP.)	2	245-2			✓✓	Cistern supplies household -13,500L (3000 gal.) capacity -goes dry 4 times per year -water quality soft Cistern supplies livestock -goes dry 6 times per year Ponds (2) -supply livestock -good water quality 2 gas wells on property (GLAL Field info.) well # 's 38 and 39 in Figure 4

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored well(s)	Cistern	Remarks
14	Mr. & Mrs. J. Morris	4 City of Niagara Falls (Formerly Crowland TWP.)	2	71-2		✓	✓	Dug/Bored well (no MOE record) -2.4m (8 ft.)deep -supplies household -water quality hard -never goes dry, spring fed Cistern supplies household and livestock -rainwater, water quality soft 2 Ponds on property -never go dry, spring fed Sand and Gravel on property 2 Gas wells on property -well # 's 42 and 43 in Figure 4
15	Mr. & Mrs. B. Warner	4 City of Niagara Falls (Formerly Crowland TWP.)	3	30-2			✓	Cistern supplies household and livestock -distilled before drinking -is filled from pond -water quality soft Pond on property -never goes dry Basement flooding in spring (house on hill)
16	Mr. G. W. Morris	4 City of Niagara Falls (Formerly Crowland TWP.)	3	112-2			✓	Cistern supplies household -water quality soft -never goes dry Pond on property Gas well on property, location unavailable, well #46 in Figure 4.

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
17	Mr. & Mrs. John Coville	2 City of Niagara (Formerly Crowland TWP.)	2 Falls	715-1			✓	Cistern supplies household -water quality soft Pond supplies livestock Gas well on property, well #44 in Figure 4
18	Mr. & Mrs. T. Chambers	8 City of Niagara (Formerly Crowland TWP.)	3 Falls	4-1				Pond on property -water quality sulphurous
19	Mr. & Mrs. Thomas Cowan	6 City of Niagara (Formerly Crowland TWP.)	3 Falls	17-2			✓	Cistern supplies household and livestock -rainwater quality soft -boiled for drinking -goes dry every 2 or 3 years -water trucked in when cistern dry Pond on property
20	Mrs. Rosina Perrotta	3 City of Niagara (Formerly Crowland TWP.)	3 Falls	509-G				2 Ponds on property

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
21	Mr. Carl Poirer	8 City of Niagara Falls (Formerly Crowland TWP.)	3	216-2			✓	Cistern supplies household -water quality soft -goes dry, purchase water from Welland
22	Mrs. Mildred Terreberry	7 City of Niagara Falls (Formerly Crowland TWP.)	3	79-1			✓	Cistern supplies household -rainwater, water quality soft -goes dry a couple of times per year Capped gas well on east side of property, well # 731 in Figure 4
23	Mr. & Mrs. James B. Rogers	7 City of Niagara Falls (Formerly Crowland TWP.)	3	85-1			✓	Cistern supplies household -rainwater, water quality soft -occasionally goes dry Bottled water used occasionally

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
24	Mr. Ivan Mamczycz	7 City of Niagara Falls (Formerly Crowland TWP.)	3	11-2	✓		✓	Cistern supplies household and livestock -rainwater -goes dry, purchase water from Welland Pond on property, spring fed -used for watering garden Drilled well (no MOE record) -abandoned, struck gas at 15.2m (50 ft.) (From GLAL Field info.)
25	Mr. Nicola Chammarco	6 City of Niagara Falls (Formerly Crowland TWP.)	3	10-2				Pond on property
26	Mr. David Warner	6 City of Niagara Falls (Formerly Crowland TWP.)	3	42-2			✓✓	2 Cisterns supply household and livestock -water purchased -water quality good -never go dry

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
27	Mr. & Mrs. Laurel McCracken and Mr. Brian McCracken	5 City of Niagara Falls (Formerly Crowland TWP.)	3	77-1			✓	Cistern supplies household -rainwater, supplemented with trucked in city water -water quality varies, city water hard, rainwater acid and salty -never goes dry Pond supplies livestock
28	Mr. & Mrs. V. Mamchych	5 City of Niagara Falls (Formerly Crowland TWP.)	3	3-1				No information available
29	Mrs. Augustine Secco	5 City of Niagara Falls (Formerly Crowland TWP.)	3	20-1				No buildings on property
30	Mr. & Mrs. J. Van Leur	5 City of Niagara Falls (Formerly Crowland TWP.)	3	73-2			✓	Cistern supplies household -rainwater -goes dry when no rain Pond on property -never goes dry

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
31	Mr. & Mrs. Walter Savoie	6 City of Niagara Falls (Formerly Crowland TWP.)	4	2-1			✓	Cistern supplies household -rainwater, water quality soft -water trucked in when cistern dry
32	Mr. Paul Evans	6 City of Niagara Falls (Formerly Crowland TWP.)	4	533-G	✓		✓	Cistern supplies household -water purchased Drilled well (MOE well 646) -not used -water quality sulphurous Gas well on adjacent property to north, well #16 in Figure 4 (see Number 56)
33	Mr. & Mrs. R. Course	6 City of Niagara Falls (Formerly Crowland TWP.)	4	106-1A			✓	Cistern supplies household -rainwater, water quality soft Pond supplies livestock -spring fed
34	Mr. W. Leishman	5 City of Niagara Falls (Formerly Crowland TWP.)	4	23-1A			✓	Cistern supplies household and livestock -rainwater, water quality soft -water filtered for cooking -never goes dry

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
35	Mr. Glen Lundy	4 City of Niagara Falls (Formerly Crowland TWP.)	4	677			✓✓	Cistern supplies household and livestock -water quality soft -goes dry 4 times per year Cistern supplies livestock -water quality soft -goes dry 4 times per year Bottled water brought in Gas wells on property, well #'s 20, and #26-28 Pond on property
36	Frontier Auto Dismantlers	7 City of Niagara Falls (Formerly Crowland TWP.)	2	24-1	✓			Drilled well (no MOE record) 27.4m (90 ft.)deep -domestic use -water quality sulphurous
		7 City of Niagara Falls (Formerly Crowland TWP.)	2	GLAL Field visit				-hit gas at 13.7m (45 ft.) -water found at 19.8m (65 ft.) -completed into bedrock -well yield 0.4-0.8 L/sec(5-10GPM)
37	Mr.Ernest Damore	5 City of Niagara Falls (Formerly Crowland TWP.)	2	28-1	✓			Drilled well (no MOE record) -50.3m (165 ft.)deep -driven casing -supplies household
38	Mr. & Mrs. B. Cowan	6 City of Niagara Falls (Formerly Crowland TWP.)	1					No information available

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
39	Mr. & Mrs. Roy Voigt	8 City of Niagara Falls (Formerly Crowland TWP.)	1	426				No information available
40	GLAL Field Notes	5 City of Niagara Falls (Formerly Crowland TWP.)	1	-				2 Oil/Gas wells,well # 's 40 and 41 in Figure 4.
41	Mr. Don Mannell	7 City of Niagara Falls (Formerly Crowland TWP.)	1	147-2	✓		✓	Drilled well (MOE well 2921) -supplies household and livestock -water quality sulphurous Cistern supplies household
		3	1	147-2				Pond on property -water stagnant
42	Mr. Archie Warner	3 City of Niagara Falls,(Formerly Crowland TWP.)	BF	25-2	✓		✓✓	Cisterns (2) supply household -water quality soft -well goes dry once in 15 years Drilled well (MOE well 618) -19.5m (64 ft.)deep -water level 6.7m (22 ft.) from surface -water quality hard, sulphurous - supplies livestock Gas well in driveway - unused, well #45 in Figure 4

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
43	Mr. Charles Warner	3 City of Niagara Falls (Formerly Crowland TWP.)	BF	48-2	✓		✓	Cistern supplies household -rainwater -goes dry once in 12 years Drilled well (no MOE record) -29.0m (95 ft.) deep -water level 7.6m (25 ft.) from surface -supplies livestock -water quality, hard, sulphurous
44	Mr. Harold A. Warner	2 City of Niagara Falls (Formerly Crowland TWP.)	BF	93-1	✓		✓	Drilled well (MOE well 616) -21.9m (72 ft.)deep -supplies household -water quality, hard, high iron content -never goes dry Cistern supplies household -rainwater and trucked in city water -never goes dry
45	Mrs. D. Pietrangelo	2 2 City of Niagara Falls (Formerly Crowland TWP.)	1 1	212-1a-1 212-1a-2				No water use reported - underground stream reported No water use reported - underground stream reported

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
46	Mr. D. Pietrangelo	2 City of Falls (Formerly Crowland TWP.)	1 Niagara	213-1A	✓		✓	Drilled well (no MOE record) -21.3m (70 ft.) deep -to supply household -new well (GLAL Field info.) Cistern supplies household -water quality soft, excellent -goes dry every couple of weeks Pond supplies livestock
47	Mr. & Mrs. Edward F. Hamilton	1 City of Falls (Formerly Crowland TWP.)	1 Niagara	529-G	✓		✓	Drilled well (no MOE record) 18.3m (60 ft.)deep -water quality salty, not potable -unused Cistern supplies household -water purchased Pond supplies livestock (i.e used for kennel) -3.6m (12 ft.)deep -never goes dry
48	GLAL Field Notes	1 City of Falls (Formerly Crowland TWP.)	1 Niagara		(✓)			Hungarian Hall reportedly has a new water well, unknown well type
49	Mr. Cheshire	12 City of (Formerly Crowland TWP.)	5 Welland	SLSA Well Survey 1968	✓			Drilled well (No MOE record) -33.5m (110 ft.)deep -water level 6.7m(22 ft.)from surface -supplies livestock -water quality hard, sulphurous -SLSA well 116

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
50	H. Brandstatter	11 City of Welland Formerly Crowland TWP.)	4	SLSA Well Survey 1968	✓			Drilled well (MOE well 648) -30.5m (100 ft.)deep -completed into overburden -SLSA well 128
51	C. Matthews	10 City of (Formerly Crowland TWP.)	4 Welland	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -well was flowing prior to June 1968 -supplies livestock -SLSA well 129
52	Mr. Eggleton	10 City of Welland (Formerly Crowland TWP.)	2	SLSA Well Survey 1968	✓			Drilled well (MOE well 632) -25.3m (83 ft.)deep -water level 10.1m (33ft.)from surface -completed into bedrock -supplies livestock -SLSA well 149
53	Mr. Dube	11 City of Welland (Formerly Crowland TWP.)	2	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -40.5m (133 ft.)deep -water level 10.1m(33 ft.)from surface -completed into bedrock -water quality, hard, sulphurous -supplies livestock -SLSA well 150

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site LF-1E Sheet 16 of 27

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
54	F. Smerk	11 City of Welland (Formerly Crowland TWP.)	1	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -31.7m (104 ft.)deep -water level 5.8m (19 ft.)from surface -supplies household -water quality hard, sulphurous -SLSA well 166
55	Mrs. Hazelton	10 City of Welland (Formerly Crowland TWP.)	1	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -30.5m (100 ft.)deep -water level 6.1m (20 ft.) from surface -completed into bedrock -supplies household and livestock -water quality sulphurous -SLSA well 167
56	Mrs. Asminskas	6 City of Niagara Falls, formerly Crowland TWP.)	4	SLSA Well Survey 1968	✓			Drilled well (MOE well 646) -24.3m (80 ft.)deep -completed into bedrock -supplies household -SLSA well 168 (see Number 32)
57	T. Williams	7 City of Niagara Falls, formerly Crowland TWP.	4	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -9.4m (31 ft.)deep -completed into overburden -supplies livestock -water quality, hard, sulphurous -SLSA well 169

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
58	V. Bielunas	6 City of Falls, formerly Crowland	4 Niagara TWP.)	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -water level 1.8m (6 ft.) from surface -supplies livestock -SLSA well 170
59	Majoros	9 City of Falls, formerly Crowland	3 Niagara TWP.	SLSA Well Survey 1968	✓			Drilled well (MOE well 640) -25.3m(83 ft.) deep -completed into overburden -water level 12.4(40.7 ft.)from surface -supplies household and livestock -water quality hard, sulphurous -SLSA well 3507
60	W. Stanley	2 City of Falls, formerly Crowland	2 Niagara TWP.	SLSA Well Survey 1968	✓ (✓)			Drilled well(may be MOE well 631) -27.4m (90 ft.)deep -completed into bedrock -water level 4.4m (14.3 ft.) from surface -supplies household and livestock -SLSA well 3508 Well (no MOE record) -9.1m (30 ft.) deep -water level 0.1m (5 inches) from surface - well type unknown

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
61	Dumele	4 City of Niagara Falls, formerly Crowland TWP.	2	SLSA Well Survey 1968		✓		Dug well (no MOE record) -3.1m (10 ft.)deep -water level 1.4m (4.5 ft.)from surface -supplies household and livestock -has never gone dry -SLSA well 3509
62	J. Horton	6 City of Niagara Falls, formerly Crowland TWP.	1	SLSA Well Survey 1968	✓		✓	Drilled well (no MOE record) -33.8m (111 ft.)deep -completed into bedrock -water level 7.0m (23 ft.) from surface -supplies livestock -water quality hard, sulphurous -has never gone dry -SLSA well 3518 Cistern supplies household
63	A. Warner	1 & 2 City of Niagara Falls, formerly Crowland TWP.	B.F.	SLSA Well Survey 1968	✓		✓	Drilled well (MOE well 616) - 19.8m (65 ft.)deep -completed into bedrock -water level 7.3m (24 ft.) from surface -supplies household and livestock -water quality, hard and sulphurous -has never gone dry -SLSA well 3519 Cistern supplies household (see Number 44)

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
64	L. Pramc	7 City of Niagara Falls, formerly Crowland TWP.)	1	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -32.0 m, (105 ft.) deep -completed into bedrock -water level 7.0m (23 ft.)from surface -supplies livestock -has never gone dry -SLSA well 3520
65	N. Kovars	9 City of Niagara Falls, formerly Crowland TWP.	2	SLSA Well Survey 1968	✓		✓	Drilled well (no MOE record) -completed into bedrock -supplies household when cistern is dry -water quality sulphurous -has never gone dry -SLSA well 3529 Cistern supplies household
66	Mr. J. Taylor	7 City of Niagara Falls, formerly Crowland TWP.	2	SLSA Well Survey 1968		✓		Dug well (no MOE record) -3.4m (11 ft.)deep -water level 2.3m (7 ft.)from surface -supplies household -water quality not sulphurous -has gone dry -SLSA well 3530 (see Number 3)
67	M. Ballantyne	6 City of Niagara Falls, formerly Crowland TWP.	2	SLSA Well Survey 1968		✓		Bored well (no MOE record) -4.9m(16 ft.)deep -water level 1.5m (5 ft.)deep -supplies household -water quality good

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
	M. Ballantyne(continued).							-has never gone dry -SLSA well 3589 (see Number 12)
68	N/A	6 City of Niagara Falls, formerly Crowland TWP.	BF	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -completed into bedrock -SLSA well no.4006
69	N/A	4 City of Niagara Falls, formerly Crowland TWP.	BF	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -completed into overburden -SLSA well no. 4115
70	N/A	1 City of Niagara Falls, formerly Crowland TWP.	1	SLSA Well Survey 1968	✓			Drilled well (MOE well 624) -completed into bedrock -SLSA well no.4159
71	N/A	7 City of Niagara Falls, formerly Crowland TWP.	1	SLSA Well Survey 1968	✓			Drilled well (MOE well 2380) -completed into bedrock -SLSA well no. 4024
72	N/A	1 City of Niagara Falls, formerly Crowland TWP.	2	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -completed into bedrock -SLSA well no.4160
73	N/A	9 City of Niagara Falls, Formerly Crowland TWP.	2	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -completed into bedrock -SLSA well no. 4120

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored well(s)	Cistern	Remarks
74	N/A	7 City of Niagara Falls, formerly Crowland TWP.	2	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -completed into bedrock -SLSA well no.4168
75	N/A	4 City of Niagara Falls, formerly Crowland TWP.	3	SLSA Well Survey 1968		✓		Dug well (no MOE record) -completed into bedrock -SLSA well no 4050
76	N/A	11 City of Niagara Falls, formerly Crowland TWP.	4	SLSA Well Survey 1968		✓		Dug well (no MOE record) -completed into overburden -SLSA well no.4238
77	N/A	8 City of Niagara Falls, formerly Crowland TWP.	4	SLSA Well Survey 1968	✓			Drilled well (MOE well 647) -completed into bedrock -SLSA well no.4080
78	GLAL FIELD NOTES	1 City of Niagara Falls, formerly Crowland TWP.	BF					Building removed - no known water use

WATER RESOURCES FORM

Interview Identification Number: _____

PHYSICAL RESOURCES - WATER

We are interested in the water used on this property: where it comes from, its quality, and how much you use.

1. What is this household's source of supply for domestic water? (e.g., drinking, laundry, toilet)

drilled water	☐	Locate on map with symbol Dr-H
dug wells	☐	Locate on map with symbol Du-H
stream water	☐	Locate on map with symbol *SW-H
cistern	☐	Locate on map with symbol *C-H
bottled water	☐	
municipal main	☐	
other, specify		_____

2. What is the water supply for the livestock and irrigation on this property?

drilled wells	☐	Locate on map with symbol Dr-A
dug wells	☐	Locate on map with symbol Du-A
streams or dams	☐	Locate on map with symbol *SW-A
cisterns	☐	
municipal main	☐	
other (e.g., ponds)		_____

3. Are there any streams or ponds on your property?

streams	Yes ☐	No ☐
ponds	Yes ☐	No ☐

4. What can you tell us about the quality of the water

a) you use or drink? (hard, soft, sulphurous, iron, salty, etc.) _____

_____

_____

b) in the streams or ponds? _____

_____

_____

5. Do the wells, cisterns or streams that you use for water supply ever go dry? If so, how often? _____

_____

_____

_____

Interview Identification Number: _____

6. Can you tell us anything about the construction of the wells? (e.g., when they were drilled, depth, type of pump, name of the driller) _____

7. Has any portion of your property been filled or excavated? If so, please show where on the map. (Locate on map with symbol EV.)

8. Do you know where there are any gas or oil wells on your property or the property you farm - in use or abandoned? Please show their locations on the map with the symbol GW.

9. Please tell us about any problems with flooding in the creeks and streams on your property. Please show locations of the flooded areas on the map. (Locate with symbol FA.) _____

8.4 BOREHOLE LOGS

8.4.1 GARTNER LEE ASSOCIATES LIMITED BOREHOLE LOGS, 1984

- SITE LF-1E
- SITE PI-27E

8.4.1 ST. LAWRENCE SEAWAY AUTHORITY BOREHOLE LOGS

8.4.1 GARTNER LEE ASSOCIATES LIMITED BOREHOLE LOGS, 1984

Borehole locations are shown in Figure 4 (in map pocket).

Borehole logs are based on field notes which have been verified by the project geologist following re-examination of samples.

Continuous samples were obtained by advancing a large split tube (8.9 cm x 152 cm) through the hollow stem augers.

Standard penetration tests were performed at 1.5 m intervals and water contents were measured in samples taken from the 'nose-piece' of the standard split spoon sampler.

Textural descriptions are provided for each geologic unit and each deposit is named (in brackets) to indicate its origin.

All material descriptions are based on visual hand sample examinations and no laboratory grain size analyses were performed. Textural descriptions are provided under 'Particle Size Classification System' in the Glossary of Selected Terms, Section 8.6.

Borehole elevations are estimated from the 1:10 000 scale base map contours. All elevations are above sea level (ASL) and are estimated to the nearest metre.

The term pebble has been used to describe gravel-sized rock particles within a fine grained matrix.

GEOTECHNICAL NOTES AND ABBREVIATIONS

Standard Penetration Resistance 'N' - The number of blows required to advance a standard split spoon sampler 30 cm into the subsoil, driven by means of a 63.5 kg hammer falling freely a distance of 75 cm.

The consistency of cohesive soils and the relative density or denseness of cohesionless soils are described as follows:

Consistency	'N' Blows per 0.3 m	Denseness	'N' Blows per 0.3 m
Very soft	0-2	Very Loose	0-4
Soft	2-4	Loose	4-10
Firm	4-8	Compact	10-30
Stiff	8-15	Dense	30-50
Very Stiff	15-30	Very Dense	> 50
Hard	> 30		

ABBREVIATIONS

WTPL - Wetter than Plastic Limit

DTPL - Drier than Plastic Limit

APL - About Plastic Limit

Wp - Plastic Limit

WL - Liquid Limit

SS - Split Spoon Sample

T - Split Tube Sample

SITE LF-1E

BOREHOLE NO. GL 1 (1E)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE September 20/84

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 180 m (approximate) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.1	TOPSOIL: very dark brown clayey silt topsoil with roots and organics, weakly developed.								
	SILTY CLAY TO CLAYEY SILT: brown to dark greyish brown silty clay to clayey silt, occasional silt laminae to 2 mm, laminated with massive zones, occasional small (<1 cm) pebble, occasional silt or clay clasts to 1 cm, heavily weathered and fractured to ±1 m, fractures with carbonate infilling and gypsum crystals 1.0-3.3 m, firm to hard, DTPL to 1.2 m, APL 1.2 to 3.1 m, WTPL below 3.1 m			1	SS	35	20		
				2	SS	11	28		
				3	SS	5	28		
	- brown/grey colour change (5.7 m)								
	- fracture with black lining and brown rusty discolouration zone (6.2 m)			4	SS	4	26		
	(Upper Glaciolacustrine Unit)			5	SS	4	23		
9.0				6	SS	4	22		
	SILTY CLAY TILL WITH INTERBEDDED SILTY CLAY TO CLAYEY SILT: brown silty clay till with interbedded silty clay to clayey silt, approximately 2/3 massive to indistinctly laminated silty clay to clayey silt till in 6 major units 0.3 to 2.6 m in thickness, approximately 1/3 laminated silty clay to clayey silt to silt in beds commonly less than 0.5 m, entire sequence is interbedded and gradational, firm to hard, WTPL (Halton Till)			7	SS	6	22		
				8	SS	6	11		
				9	SS	5	21		
				10	SS	57	16	STONE	
	- 20 cm thick bed of silty fine sand saturated (16.9-17.1 m)			11	SS	19	18		
				12	SS	12	13		
				13	SS	6	12		
				14	SS	20	13		
				15	SS	22	18		
24.2	SILTY CLAY TO CLAYEY SILT: (see next page)			16	SS	13	40		

BOREHOLE NO. GL 1 (1E) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation

DATE September 20/84

BOREHOLE TYPE 108 mm ID Hollow-Stem Auger, Continuous Sampling

GEOLOGIST AB/AC

GROUND ELEVATION 180 m (approximate)

PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) COMMENTS
27.0	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, well laminated with silt laminae to 2 mm, occasional small (<1 cm) pebble, occasional silt or clay clasts to 1 cm, stiff, WTPL (Lower Glaciolacustrine Unit)			17	SS	10	27		Wp — Wl
	SILT TILL: dark grey silt till, sandy to clayey, basal 2 m, transitional to weathered bedrock, up to 85% crushed rock, loose to very dense (Lower Till)			18	SS	8	9		
				19	SS	42	8		
	- 10 cm thick inclusion of silty fine sand			20	SS	25	3		
				21	SS	50	6		
				23	SS	*	8	* 52/0.15 m →	
				24	SS	*	7	* 50/0.05 m →	
36.7				25	SS	*	11	* 93/0.15 m →	
	DOLOSTONE: medium grey, fine grained dolostone, with dark grey to black shale partings to 0.5 cm thick, occasional vugs to 1 cm, occasional white gypsum in vugs or along shale partings or fractures in rock. (Guelph Formation)								
39.6	Borehole terminated at 39.6 m in dolostone								

Gartner Lee Associates Limited

BOREHOLE NO. GL 2 (1E)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE September 20/84

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling GEOLOGIST EJK/AC

GROUND ELEVATION 181 m (approximate) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER
0.2	TOPSOIL: very dark greyish brown clayey silt topsoil, occasional roots						
	SILTY CLAY TO CLAYEY SILT: brown to dark greyish brown silty clay to clayey silt, generally laminated with massive zones, silt laminae to 2 mm are common, occasional small (<1 cm) pebble, occasional silt or clay clasts to 1 cm, heavily weathered and fractured in upper ±1 m, discoloured fractures at 2.5 m, 3.0 m, 4.8 m, 5.5 m, 7.0 m, discoloured silt laminae at 5.4 m and 6.0 to 6.3 m, very stiff, APL to 4.0 m, WTPL below 4.0 m (Upper Glaciolacustrine Unit)			1	SS	28	22
				2	SS	26	20
				3	SS	30	23
				4	SS	22	21
				5	SS	26	24
				6	SS	19	21
				7	SS	16	20
11.7	CLAYEY SILT TO SANDY SILT TILL: brown clayey silt to sandy silt till, variable, with several till-like sub-units, massive to laminated, inclusions of silt and silt till, very stiff to hard, WTPL (Halton Till)			8	SS	26	13
				9	SS	24	9
	BOULDER @ 15.7 m			10	SS	18	11
				11	N/A	N/A	N/A
				12	NA	N/A	N/A
				13	SS	49	14
				14	SS	41	8
20.9	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, well laminated with red and grey banding, occasional silt lamina to 3 mm, occasional small pebble (to 1 cm) occasional silt or clay clasts (to 1 cm), stiff, WTPL (Lower Glaciolacustrine Unit)			15	SS	13	27
23.4				16	SS	N/A	29
	SANDY SILT TO SILTY SAND TILL: dark greyish brown sandy silt to silty sand till, increasing gravel downward (Continued)			17	SS	*	14

PENETRATION RESISTANCE BLOWS/0.3m (20, 40, 60)

WATER CONTENT % (10, 20, 30; Wp, Wl) / COMMENTS

* 70/0.08 m

Auger refusal 24.22

Gartner Lee Associates Limited

BOREHOLE NO. GL 2 (1E) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE September 20/84

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling GEOLOGIST EJK/AC

GROUND ELEVATION 181 m (approximate) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) Wp — Wl / COMMENTS
	SANDY SILT TO SILTY SAND TILL: (continued) numerous broken shale fragments, occasional white gypsum pebbles, very dense, saturated (Lower Till)								
27.1	SHALE: medium grey dolomitic shale to shaly dolostone, massive to finely bedded, approximately one quarter of core is white gypsum nodules (Salina Formation)			19	SS	*	9	* 80/0.14 m →	BOULDER
28.3	Borehole terminated at 28.3 m in shale								

Gartner Lee Associates Limited

BOREHOLE NO. GL 3 (1E)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE September 19/84

BOREHOLE TYPE 108 mm ID Hollow Stem Auger ,Continuous Sampling GEOLOGIST EJK/AC

GROUND ELEVATION 180 m (approximate) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS
0.1	TOPSOIL: very dark grey clayey silt topsoil, roots, organics and twigs							20 40 60	10 20 30 Wp Wl
	CLAYEY SILT TO SILTY CLAY: dark grey to brown clayey silt to silty clay, laminated with massive zones, occasional silt lamina to 2 mm, occasional pebbles to 1 cm, occasional silt or clay clasts to 1 cm, heavily weathered and fractured in upper ±1 m, fractures with discolouration occur at 1.8 m and 6.3 m, silt laminae with discolouration occur at 3.2 to 4.2 m, 4.3 to 4.5 m, 4.8 to 5.6 m and 6.3 m, firm to very stiff, APL to 3.6 m, WTPL below 3.6 m (Upper Glaciolacustrine Unit)			1	SS	24	23		
				2	SS	14	20		
				3	SS	11	23		
				4	SS	10	24		
				5	SS	7	24		
				6	SS	6	24		
				7	SS	12	26		
12.7	CLAYEY SILT TO SILT TILL: brown clayey silt to silt till, massive to indistinctly laminated, very stiff, WTPL (Halton Till)			8	SS	10	25		
				9	SS	27	17		
14.2	SANDY SILT TILL: brown sandy silt till, numerous large pebbles and cobbles to maximum sample size, very dense, saturated (Lower Till)			10	SS	*	N/A	* 30/0.02 m →	BOULDER
				11	SS	*	7	* 50/0.08 m →	ONE/BOULDER
17.8	Borehole terminated at 17.8 m in till (probable boulder) gas encountered at 17.8 m								

Gartner Lee Associates Limited

BOREHOLE NO. GL 4 (1E)

PROJECT NAME: Phase 4A Drilling and Sampling

CLIENT: Ontario Waste Management Corporation — DATE: September 25/84

BOREHOLE TYPE: 108 mm ID Hollow Stem Auger ,Continuous Sampling — GEOLOGIST: EJK/AC

GROUND ELEVATION: 180 m (approximate) — PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: very dark greyish brown clayey silt topsoil, with roots and vegetation.								
	CLAYEY SILT TO SILTY CLAY: dark greyish brown clayey silt to silty clay, laminated, with occasional pebbles to 1 cm, occasional silt or clay clasts to 1 cm, occasional silt lamina to 1 mm, heavily weathered to ±2 m, grey carbonate-lined fractures common to 4.1 m, rusty brown-stained grey carbonate-lined fractures at 4.5 and 4.8 m, several grey carbonate-lined fractures to 4.9 m, colour break observed at ±5.9 m, silt lamina with rusty discolouration at 6.3 m, firm to hard, DTPL to 2.6 m, APL 2.6 to 5.9 m WTPL below 5.9 m (Upper Glaciolacustrine Unit)			1	SS	36	19		
				2	SS	30	24		
				3	SS	22	32		
				4	SS	15	24		
				5	SS	7	24		
				6	SS	11	23		
				7	SS	14	28		
	} fine sandy silt (12.3 to 12.6 m)			8	SS	11	19		
14.1				9	SS	*	25	* 3/0.15 m	
	SILTY VERY FINE SAND: reddish brown silty very fine sand, interbedded with silt, fine sand and occasional clay lamina, loose to compact, saturated (Upper Glaciolacustrine Unit)			10	SS	15	25		
				11	SS	3	22		
18.1									
	SILT TILL: brown silt till, variable, massive to indistinctly laminated, gradational upper contact, sharp lower contact, occasional silt or fine sand inclusions to 3 cm, rusty brown discolouration along silt sandy fine gravel parting (3 cm thick) at 21.1 m, dark greyish brown 21.4 to 21.7 m, dense to very dense, saturated (Halton Till)			12	SS	38	14		
				13	SS	*	9	* 75/0.21 m →	
				14	SS	*	8	* 69/0.15 m →	
22.6									
	SANDY SILT TILL: dark greyish brown sandy silt till, massive to indistinctly laminated, minor clay content, occasional sandy zone, increase in gravel content to bedrock, saturated, very dense (Lower Till)			15	SS	*	7	* 60/0.15 m →	
				16	SS	*	9	* 60/0.15 m →	
									Auger Refusal @24.26 m

Gartner Lee Associates Limited

BOREHOLE NO. GL 4 (1E) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE September 25/84

BOREHOLE TYPE 108mm ID Hollow Stem Auger, Continuous Sampling GEOLOGIST EJK/AC

GROUND ELEVATION 180 m (approximate) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
	(continued)								
25.9	SHALE AND GYPSUM: dark grey dolomitic shale with white gypsum, shale is banded and interbedded with gypsum stringers, massive white gypsum zones with minor shale, approximately equal portions of shale and gypsum. (Salina Formation)			17	SS	*	9	* 100/0.15 m →	
28.5	Borehole terminated at 28.5 m in shale and gypsum.								

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BOREHOLE NO. GL 5 (1E)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE September 25/84

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 183 m (approximate) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER
0.2	TOPSOIL: very dark greyish brown clayey silt topsoil, numerous roots and organics.						
	SILTY CLAY TO CLAYEY SILT: brown to dark greyish brown silty clay to clayey silt, laminated to massive with occasional silt laminae to 2 mm thick, occasional pebble to 1 cm, occasional silt or clay clasts to 1 cm, heavily weathered and fractured to ±2 m, colour change at ±5.2 m, fracture with grey carbonate infilling at 5.2 m, firm to very stiff, DTPL to 2.7 m, APL 2.7 to 4.0 m, WTPL below 4.0 m (Upper Glaciolacustrine Unit)			1	SS	27	18
				2	SS	22	20
				3	SS	13	23
				4	SS	7	21
				5	SS	4	18
9.0							
	SILTY VERY FINE SAND: reddish brown silty very fine sand to fine sandy silt, occasional silty clay lamina, occasional pebble to 0.5 cm, compact, saturated (Upper Glaciolacustrine Unit)			6	SS	12	20
				7	SS	13	18
11.4							
12.7	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, massive with indistinct laminations, occasional pebble to 1 cm, stiff (Upper Glaciolacustrine Unit)			8	SS	12	16
	CLAYEY SILT TO SILT TILL: brown clayey silt to silt till, pebbles and cobbles to 8 cm, upper and lower contacts gradational, massive inclusion of silty fine sand 10 cm thick at 18.3 m, stiff to hard, WTPL (Halton Till)			9	SS	9	16
				10	SS	27	16
				11	SS	11	16
				12	SS	13	18
19.8				13	SS	44	16
	INTERBEDDED SILT, FINE SAND AND SILTY CLAY: reddish brown to brown laminated interbedded silt, fine sand and silty clay, fine sand dominant 19.8 to ±23 m, silt and clay dominant ±23 to 24.8 m, occasional pebbles to 2 cm, sand is saturated, silty clay APL to WTPL (Lower Glaciolacustrine Unit)			14	SS	41	10
				15	SS	36	14
				16	SS	25	26
24.8							

PENETRATION RESISTANCE BLOWS/0.3m: 20 40 60

WATER CONTENT % / COMMENTS: 10 20 30; Wp — Wl

Gartner Lee Associates Limited

BOREHOLE NO. GL 5 (1E) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation — DATE September 25/84

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling — GEOLOGIST AB/AC

GROUND ELEVATION 108 m (approximate) — PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) Wp—Wl / COMMENTS
	SANDY SILT TILL: dark greyish brown sandy silt till, increasing gravel content with depth particularly beneath 27.8 m, gradational to underlying bedrock, saturated, very dense (Lower Till)			17	SS	*	7	* 95/0.15 m →	
				18	SS	74	12		
28.3	DOLOSTONE: light to medium grey fine-grained dolostone with shale partings, occasional vugs (<1 cm), occasional rock fractures filled with gypsum (Guelph Formation)								
30.7	Borehole terminated at 30.7 m in dolostone								

BOREHOLE NO. GL 6 (1E)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** September 17/84

BOREHOLE TYPE 108mm ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 185 m (approximate) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
0.1									
0.3	TOPSOIL: very dark greyish brown sandy silt to silty sand topsoil, with roots								
	MEDIUM TO COARSE SAND: grey medium to coarse sand with gravel			1	SS	72	10		
	SILT TO SANDY SILT TILL: reddish brown silt to sandy silt till with beds of intermixed silty fine sand to 0.6 m, numerous sand inclusions to 5 cm thick, occasional pebbles to 3 cm, approximately 30% silty fine sand, very dense, moist (Halton Till)			2	SS	*	12	*96/0.10 m →	
4.1				3	SS	70	9		
	SILTY FINE SAND: brown to reddish brown silty fine to very fine sand with inclusions of brown silty clay till, occasional lamina of silt and clay, occasional pebble to 3 cm, dense, saturated			4	SS	36	17		
7.6				5	SS	75	NA		
	SILT TO SANDY SILT TILL: reddish brown silt to sandy silt till, sandy to silty zones in horizontal bands, occasional sand and silt inclusions common to 0.5 cm thick - occasionally to ±10 cm, very dense, saturated (Halton Till)			6	SS	NA	11		
10.0				7	SS	49	15		
	SILTY FINE TO MEDIUM SAND: grey to reddish brown silty fine to medium sand, occasional silt lamina to 1.5 cm, occasional silt clast to 1.5 cm, dense, saturated			8	SS	42	NA		
				9	SS	49	15		
14.8				10	SS	52	NA		
	CLAYEY SILT TILL: brown clayey silt till, with numerous sand, silt and clay lamina and inclusions, laminated to massive, occasionally contorted, variable pebble content, approximately 20% sand, silt and clay inclusions, hard, WTPL (Halton Till)			11	SS	47	14		
				12	SS	58	NA		
20.1				13	SS	61	14		
	CLAYEY SILT TO SILTY CLAY: brown clayey silt to silty clay, laminated, contorted in places, occasional pebbles to 6 cm, occasional silt laminae to 2 mm, hard, WTPL (Lower Glaciolacustrine Unit)			14	SS	48	16		
				15	SS	50	22		
				16	SS	56	18		

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BOREHOLE NO. GL 6 (1E) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE September 17/84

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 185 m (approximate) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
	CLAYEY SILT TO SILTY CLAY: (continued)			17	SS	50	18		
				18	SS	30	27		
28.2	SANDY SILT TILL: brown to dark grey sandy silt till, inclusions of fine to medium sand 28.5 m to 29.9 m, increasing gravel content (to ±90%) with depth, gravel is angular dark grey dolostone with occasional gypsum pebble, saturated, very dense (Lower Till)			19	N/A	N/A	N/A	NO SAMPLE	BOULDER
				20	SS	*	7	* 60/0.13 m →	
				21	SS	*	8	* 60/0.08 m →	
34.3	Borehole terminated at 34.3 m (probably on bedrock)								

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SITE PI-27E

BOREHOLE NO. GL 2 (27E)

PROJECT NAME Phase 4A Drilling And Sampling

CLIENT Ontario Waste Management Corporation **DATE** September 7, 1984

BOREHOLE TYPE 108 mm. I.D.Hollow Stem Auger, Continuous Sampling **GEOLOGIST** A.B./A.C.

GROUND ELEVATION 180 m. (approximate) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) COMMENTS
0.4	TOPSOIL: very dark greyish brown clayey silt, numerous roots								
	SILTY CLAY TO CLAYEY SILT: dark grey to brown silty clay to clayey silt, laminated with occasional silt lamina to 1 mm, occasional small (<1 cm) pebbles, upper ±1.1 m heavily weathered with grey lined fracture traces, silt zone 1.8 to 2.0 m, mainly clayey silt 8.5 m to 10.0 m, soft to stiff, APL 0 to 1.9 m, WTPL below 1.9 m (Upper Glaciolacustrine Unit)			1	SS	5	28		
				2	SS	9	23		
				3	SS	5	24		
				4	SS	5	24		
				5	SS	7	23		
				6	SS	2	26		
10.0	SILTY CLAY TO CLAYEY SILT TILL: brown silty clay to clayey silt till with pebbles, massive to indistinctly laminated, disturbed silty fine sand inclusion at 11.3 m (maximum 20 cm thick), upper and lower contacts gradational, firm WTPL (Halton Till)			7	SS	6	22		
				8	SS	4	20		
13.5	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, laminated, occasional silt lamina to 2 mm, occasional small (<1 cm) pebbles, WTPL (Lower Glaciolacustrine Unit)			9	SS	4	25		
14.3				10	SS	19	12		
	SILT TO SANDY SILT TILL: brown silt to sandy silt till, variable with inclusions of clayey silt, numerous broken pebbles, numerous pebbles in lower portion, lower contact gradational over 1.5 m to bedrock, saturated, compact to very dense (Lower Till)			11	SS	60	7		
17.6				12	SS	*	N/A	* 80/0.10 m	NO SAMPLE
	DOLOSTONE: medium grey, fine-grained dolostone with shale partings, occasional gypsum (to 3 mm thick) along shale bedding planes (maximum 0.5 cm thick), occasional vugs. (Guelph Formation)								
20.9	Borehole terminated at 20.9 m in dolostone.								

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BOREHOLE NO. GL 4 (27E)

PROJECT NAME Phase 4A Drilling And Sampling

CLIENT Ontario Waste Management Corporation **DATE** September 14, 1984

BOREHOLE TYPE 108mm I.D.Hollow Stem Auger, Continuous Sampling **GEOLOGIST** E.J.K./A.C.

GROUND ELEVATION 178 m. (approximate) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) WP — WL / COMMENTS
0.2	TOPSOIL: very dark grey clayey silt topsoil with roots and vegetation								
	SILTY CLAY TO CLAYEY SILT: dark greyish brown to reddish brown silty clay to clayey silt, well laminated with occasional silt laminae to 2 mm or larger as noted, occasional pebbles to 2 cm, heavily weathered and fractured to ±1 m, colour change observed at ±2.7 m, fractures with grey carbonate infilling and/or rusty discolouration observed 3.0 to 3.4 m, 3.6 to 3.8 m, 4.6 m and 5.1 m, soft to very stiff, WTPL 0 to 0.5 m, APL 0.5 to 2.5 m, WTPL below 2.5 m (Upper Glaciolacustrine Unit)			1	SS	26	21		
				2	SS	14	28		
				3	SS	6	12		
				4	SS	5	26		
				5	SS	3	21		
8.6									
	SILTY CLAY TO CLAYEY SILT TILL: brown silty clay to clayey silt till, massive to laminated with pebbles and silt or clay clasts, firm to hard, WTPL (Halton Till)			6	SS	23	22		
				7	SS	7	22		
				8	SS	7	20		
				9	SS	7	21		
				10	SS	84	10		
16.2									
	SILTY FINE SAND: grey to reddish brown silty fine to very fine sand, occasional zones of sandy silt and clayey silt, occasional pebbles to 4 cm, occasional clay clasts to 1 cm, medium to coarse sand dominant below ±25 m, compact to very dense, saturated (Lower Glaciolacustrine Unit)			12	SS	68	8		
				13	SS	95	17		
				14	SS	10	30		
	- Gas at 22.5 m			15	SS	20	20		
				17	SS	43	12		
25									

Gartner Lee Associates Limited

BOREHOLE NO. GL 4 (27E) (cont'd)

PROJECT NAME Phase 4A Drilling And Sampling

CLIENT Ontario Waste Management Corporation — DATE September 14, 1984

BOREHOLE TYPE 108 mm I.D.Hollow Stem Auger,Continuous Sampling — GEOLOGIST E.J.K./A.C.

GROUND ELEVATION 178 m. (approximate) — PROJECT NO. 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) WP WL / COMMENTS
25	SILTY FINE SAND: (cont'd)			18	SS	49	16		
				19	SS	57	11		
				20	SS	100	7		
				21	SS	*	N/A	* 75/0.02 m →	NO SAMPLE
30.4	- Gas at 30.4 m								
	Borehole Terminated at 30.4 m in silty fine sand on a boulder								

Gartner Lee Associates Limited

BOREHOLE NO. GL 5 (27E)

PROJECT NAME Phase 4A Drilling And Sampling

CLIENT Ontario Waste Management Corporation

DATE September 12, 1984

BOREHOLE TYPE 108 mm I.D.Hollow Stem Auger,Continuous Sampling

GEOLOGIST E.J.K./A.C.

GROUND ELEVATION 178 m. (approximate)

PROJECT NO. 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) Wp Wl COMMENTS
0.2	FILL: slag and silty fill (till)								
0.4	TOPSOIL: very dark brown silty clay to clayey silt topsoil with organics and roots								
	CLAYEY SILT TO SILTY CLAY: dark grey to brown clayey silt to silty clay, laminated with occasional silt lamina to 2 mm, heavily weathered to ±1 m, numerous fractures with grey carbonate infilling to 2.4 m, brown/grey colour change at ±3.7 m, occasional pebbles (to 1 cm), 8 fractures with rusty brown stain between 4.0 and 5.1 m brown stained fractures at 5.9m and 6.4 m, unstained silt lamina (0.5 cm thick) at 14.2 m, firm to hard, OTPL to 4.1 m, WTPL below 4.1 m (Upper Glaciolacustrine Unit)			1	SS	19	22		
				2	SS	37	23		
				3	SS	12	33		
				4	SS	16	21		
				5	SS	22	24		
				6	SS	7	23		
				7	SS	10	26		
				8	SS	10	24		
	SILT TILL: brown sandy to clayey silt till, pebble content variable, massive to indistinctly laminated (Halton Till)			9	SS	N/A	22		
15.7	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, laminated with silt layers to 0.5 cm occasional pebbles to 1 cm (Lower Glaciolacustrine Unit)			10	SS	18	22		
16.5									
16.7	SANDY SILT TILL: brown sandy silt till, saturated, very dense (Lower Till)			11	SS	54	6		
17.4									
18.7	DOLOSTONE: light to medium grey, fine-grained dolostone with occasional shale partings to 4 mm, occasional vugs comprise up to 10% of volume (Guelph Formation)								
	Borehole terminated at 18.7 m in dolostone								

Gartner Lee Associates Limited

8.4.2. ST. LAWRENCE SEAWAY AUTHORITY BOREHOLE LOGS

Borehole locations are shown in Figure 4 (in map pocket).

Borehole elevations are provided to the nearest tenth of a foot in the original data. Elevations have been rounded to the nearest metre in Figure 4.

Borehole logs are photo-reduced from copies supplied by the St. Lawrence Seaway Authority in St. Catharines and are on file.

8.4.2 ST. LAWRENCE SEAWAY AUTHORITY BOREHOLE LOGS

SLSA 1199

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO W1199

CHAINAGE 100+2[illegible] OFFSET 4
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE 595.9 BOTTOM HOLE 555.9
BEDROCK GROUNDWATER

ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLER TYPE & SIZE	SAMPLE NO.	ELEV. / DEPTH
	ORGANIC TOPSOIL DARK BROWN		DO	1	
	SILTY CLAY, TRACE OF SAND; OCCASIONAL SMALL SILT INCLUSIONS AND PARTINGS (CH, CI)			2 3 4 5 6 7	
	CLAYEY SILT, TRACE OF SAND, BROWN, OCCASIONAL GRAVEL & ROCK FRAGMENTS TO 12" WITH SILT INCLUSIONS AND PARTINGS (TILL-LIKE) (Mi-CL)			8 9 10	
575.9 / 20	CLAYEY SILT BROWN, DENSE (Mi-CL)			10	20
	WITH INCLUSIONS FINE SANDY SILT			11	
	CLAYEY SILT, TRACE OF SAND, GREYISH BROWN, OCCASIONAL PARTICLES OF SUB-ANGULAR GRAVEL AND ROCK FRAGMENTS TO 12", TILL (CL) WITH ZONES TO 7" OF FINE BROWN SANDY SILT			12	
555.9 / 40				13	40
	SANDY SILT, TRACE OF CLAY BROWN, PARTICLES OF SUB-ANGULAR GRAVEL AND ROCK FRAGMENTS TO 12", DENSE TILL (Mi-CL)			14	50
535.9 / 60	BOTTOM OF HOLE 60.0'			15	60

WATER CONTENT % — w_p — w — w_l (10 20 30 40 50 60)

NATURAL WET DENSITY P.C.F. (110 120 130 140)

SHEAR STRENGTH (P.S.F.) TYPE: UNCONFINED, QUICK TRIAXIAL, VANE — UNDISTURBED, REMOULDED (1000 2000 3000 to 4000)

STANDARD PENETRATION TEST BLOWS/FT. (20 40 60 80 100)

PARTICLE SIZE % (20 40 60 80)

WATER DROP INCREMENT (INCHES/5 MINS.)

ELEV. / DEPTH (10 20 30 40 50 60)

REMARKS: PENN CENTRAL W C LINE BORING - 6

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN	GEOTECHNICAL PROFILES
CHECKED	
EXAMINED	RECOMMENDED: APPROVED: DATE: JUNE 2, 1969 BORING NO: W1199

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO W1200

CHAINAGE 103+50 OFFSET 4
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE BOTTOM HOLE
BEDROCK GROUNDWATER

ELEV. / DEPTH	DESCRIPTION	SAMPLE NO.	ELEV. / DEPTH
	SILTY CLAY, TRACE OF SAND, BROWN, OCCASIONAL PARTICLES OF SUB-ANGULAR GRAVEL AND ROCK FRAGMENTS TO 1/4", TILL (CL)	1	10
20	SANDY SILT, BROWN, OCCASIONAL SUB-ANGULAR GRAVEL TO 1", TILL (ML) WITH INCLUSIONS OF SILTS, SMALL LENSES CLAY	2, 3, 4, 5	30
40	CLAYEY SILT, TRACE OF SAND GREYISH BROWN, OCCASIONAL SUB-ANGULAR GRAVEL AND ROCK FRAGMENTS TO 1" (TILL-LIKE) WITH ZONES OF MEDIUM SAND. (CL)	6, 7	40
	ONLY RECOVERY: ROCK FRAGMENTS AND SMALL CHUNKS OF BROWN SANDY SILT (STONY) TILL	8	50
62.5	TOP OF BEDROCK 60.3		
	BOTTOM OF HOLE 78.7		70

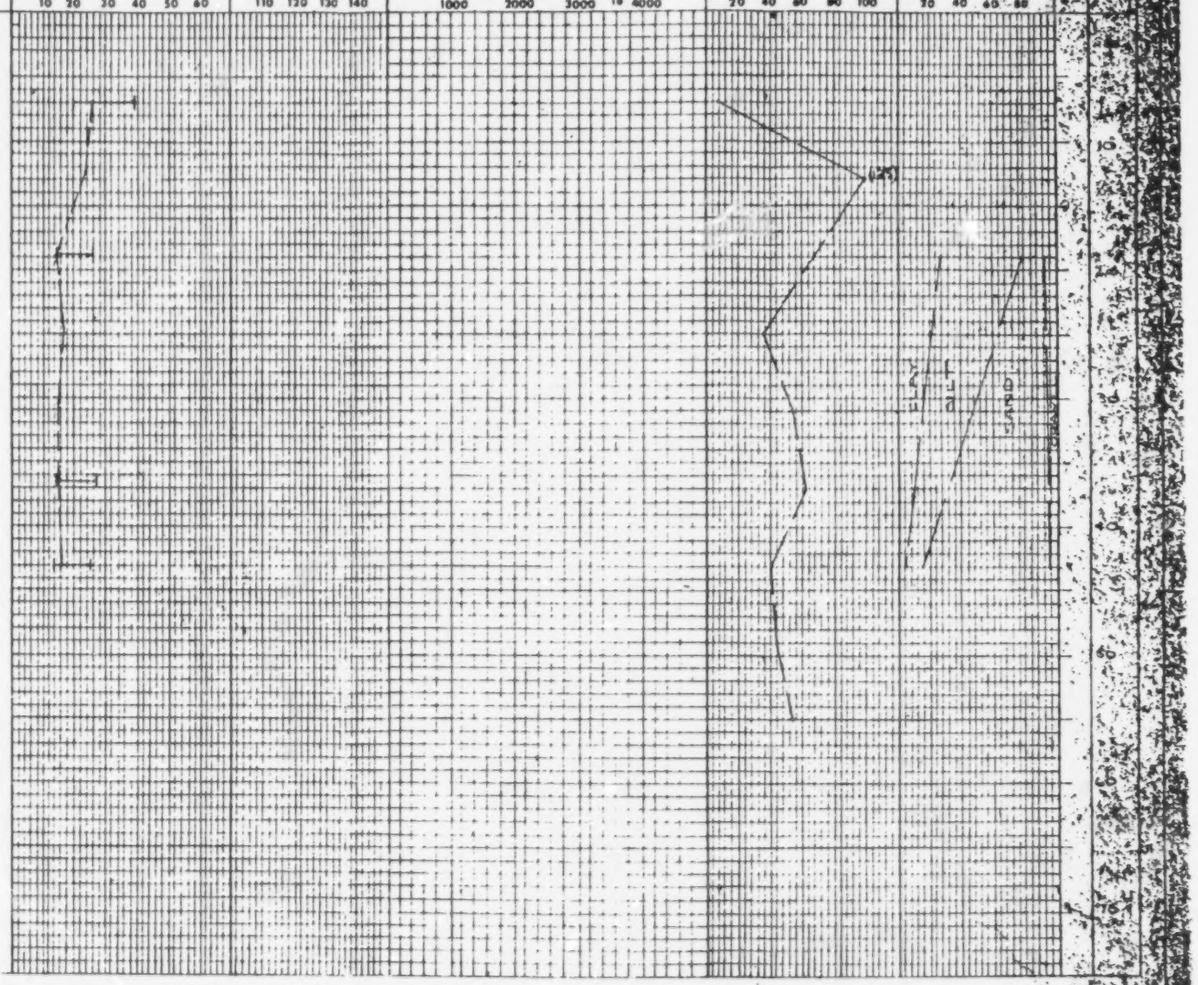
WATER CONTENT % — 10 20 30 40 50 60

NATURAL WET DENSITY P.C.F. — 110 120 130 140

SHEAR STRENGTH (P.S.F.) — TYPE: UNCONFINED, QUICK-TRIAXIAL, VANE; UNDISTURBED ● ▲, REMOULDED ○ △; STRAIN 15 0 5; 1000 2000 3000 10 4000

STANDARD PENETRATION TEST BLOWS/FT — 20 40 60 80 100

PARTICLE SIZE % — 20 40 60 80



ELEV. / DEPTH

REMARKS: PENN CENTRAL R-S LINE
CHAINAGE RE PENN CENTRAL
-SAMPLE RECOVERY IN GENERAL POOR
BORING 5-1A

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN	GEOTECHNICAL PROFILES
CHECKED	
EXAMINED	RECOMMENDED / APPROVED / DATE / DRAWING NO.

SLSA 1201

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO W1201
CHAINAGE 105+32 OFFSET 4
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE BOTTOM HOLE
BEDROCK GROUNDWATER

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLER TYPE & SIZE	SAMPLE No.	ELEV. DEPTH
	SILTY CLAY, TRACE OF SAND; BROWN TO BLACK, OCCASIONAL GRAVEL TO 2", ORGANIC INCLUSIONS, (CL) BOULDER		D	1	
10	CLAYEY SILT, TRACE OF SAND, BROWN, FIRM, OCCASIONAL SUB ANGULAR GRAVEL AND BOULDERS, TILL (CL)		D	2	10
			D	3	
20	LAYERED SILTS (BROWN) AND SILTY CLAYS (REDDISH BROWN)		D	4	20
	CLAYEY SANDY SILT, REDDISH BROWN, NUMEROUS LENSES OF GRAVEL (ANGULAR TO SUB-ROUNDED), ALSO ROCK FRAGMENTS TO [illegible] DENSE TILL [illegible]		D	NR	
			D	5	
30	TOP OF BEDROCK 29.1 BOTTOM OF HOLE 25.5		D	6	30
			CB		
40					40

WATER CONTENT %
w_p ——— w ——— w_L
10 20 30 40 50 60

NATURAL WET DENSITY P.C.F.
110 120 130 140

SHEAR STRENGTH (P.S.F.)
TYPE: UNCONFINED, QUICK TRIAXIAL, VANE
UNDISTURBED ⊕ ● ▲ REMOULDED ⊖ ○ △
STRAIN IN %
1000 2000 3000 10 4000

STANDARD PENETRATION TEST
BLOWS/FT
20 40 60 80 100

PARTICLE SIZE %
70 40 60 80

WATER DROP (WT/2 IN.)

ELEV. DEPTH
10
20
30
40

REMARKS: [illegible]

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN L.A.M.	GEOTECHNICAL PROFILES
CHECKED	
EXAMINED	

RECOMMENDED	APPROVED	DATE	BORING NO
		APR 28/69	W1201

SLSA 1202

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO W202
CHAINAGE 12+95 OFFSET L
CO-ORDINATES: N E

ELEVATION
GROUND SURFACE 591 BOTTOM HOLE 581.7
BEDROCK 581.7 GROUNDWATER

ELEV. DEPTH	DESCRIPTION	STRAT PLOT	SAMPLED TYPE & SIZE	SAMPLE No.	ELEV. DEPTH
				1	
				2	
				3	
				4	
				5	
				6	
				8	
				10	

WATER CONTENT % — w_p w w_l — 10 20 30 40 50 60

NATURAL WET DENSITY PCF — 110 170 130 140

SHEAR STRENGTH (P.S.F.) — TYPE: UNCONFINED, QUICK TRIAXIAL, VANE — UNDISTURBED ● ▲ — REMOULDED ⊗ ○ △ — STRAIN 15 : 5 — 1000 2000 3000 10 4000

STANDARD PENETRATION TEST BLOWS/FT — 20 40 60 80 100

PARTICLE SIZE % — 20 40 60 80

WATER DROP (INST. 2 MIN.)

ELEV. DEPTH
10
20
30
40
50

REMARKS:

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN	GEOTECHNICAL PROFILES
CHECKED	
EXAMINED	RECOMMENDED / APPROVED / DATE APRIL 28/58 / BORING NO W1202

SLSA 1203

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO W1203
CHAINAGE 109 + 80 OFFSET ℄
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE 582.5 BOTTOM HOLE 522
BEDROCK 522 GROUNDWATER

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLER TYPE & SIZE	SAMPLE NO.	ELEV. DEPTH
	SILTY CLAY, TRACE OF SAND, MEDIUM BROWN		SS	1	
	SILT, BROWN		SS	2	10
	CLAYEY SILT, TRACE OF SAND, BROWN, OCCASIONAL GRAVEL TO 1"		SS	3	
	BROWN, WEATHERED		SS	4	
562.5 20	LAYEY SILT, TRACE OF SAND; PARTICLES OF SUB ANGULAR GRAVEL AND ROCK FRAGMENTS TO 14" TILL (GLACIAL) GREYISH BROWN		SS	5	20
			SS	6	
	ROCK FRAGMENTS AND SILTY SAND RECOVERED ONLY		SS	7	30
542.5 40	BOULDERS AND CLAYEY SANDY SILT TILL		CH	8	
			CE	9	40
			CE	10	50
			FE	11	
522.5 60	TOP OF BEDROCK 60.0 BOTTOM OF HOLE 77.5		CB	12	60

WATER CONTENT % — w_p ⊢ w ⊣ w_L — 10 20 30 40 50 60

NATURAL WET DENSITY P.C.F. — 110 120 130 140

SHEAR STRENGTH (P.S.F.) — TYPE: UNCONFINED ● QUICK TRIAXIAL ▲ VANE ▲ — UNDISTURBED ⊕ — REMOULDED ⊖ — STRAIN IS : 5 10 — 1000 2000 3000 4000

STANDARD PENETRATION TEST BLOWS/FT — 20 40 60 80 100

PARTICLE SIZE % — 20 30 60 80

WATER DROP INS. 2 MIN

ELEV. DEPTH
0
20
40
60

REMARKS: PENN CENTRAL RELOCATION - R S LINE
CHAINAGES - RE PENN CENTRAL

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN	GEOTECHNICAL PROFILES
CHECKED	
EXAMINED	RECOMMENDED / APPROVED / DATE MAY 8, 1967 / BORING NO. W1203

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO W 1218
CHAINAGE 112 + 20 OFFSET 3
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE 569.1 BOTTOM HOLE 561.7
BEDROCK GROUNDWATER

ELEV. / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLER TYPE & SIZE	SAMPLE No.	ELEV. / DEPTH
	SILT AND CLAY WITH INCLUSIONS OF BLACK ORGANIC MATERIAL TRACE OF SAND, BROWN, OCCASIONAL INCLUSIONS OF LIGHT BROWN TO REDDISH BROWN SILT, FISSURED		DO	1 2 3 4 5	
559.1 10	SILTY CLAY, TRACE OF SAND, BROWN, MOTTLED REDDISH BROWN AND GREY, LAYERING, OCCASIONAL GRAVEL AND ROCK FRAGMENTS TO 1½"			6	10
	SILT AND CLAYEY SILTS LAMINATED AND LENSED, DENSE			7	
549.1 20	BROWN OCCASIONAL GRAVEL AND ROCK FRAGMENTS TO 1" SANDY SILT SOME CLAY TILL (NIAGARA)			8	20
	DARK BROWN WITH NUMEROUS PARTICLES OF GRAVEL & ROCK FRAGMENTS TO 12" BOULDERS			9	30
533.1 36	BOTTOM OF HOLE 36.4			10	40

WATER CONTENT % — 10 20 30 40 50 60
NATURAL WET DENSITY P.C.F — 110 120 130 140
SHEAR STRENGTH (P.S.F) — TYPE: UNCONFINED, QUICK TRIAXIAL, VANE; UNDISTURBED, REMOULDED; STRAIN 1% 5% 10%; 1000 2000 3000 4000
STANDARD PENETRATION TEST BLOWS/FT — 20 40 60 80 100
PARTICLE SIZE % — 20 40 60 80
WATER DROP INS/3 MIN

REMARKS: PENN CENTRAL, R-S LINE BORING - B 16

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN	GEOTECHNICAL PROFILES
CHECKED	
EXAMINED	

RECOMMENDED	APPROVED	DATE	BORING No.
		MAY 19/69	W 1218

SLSA 1219

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO W1219
CHAINAGE 120+00 OFFSET 4
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE 600.6 BOTTOM HOLE 550.6
BEDROCK GROUNDWATER

ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLER TYPE & SIZE	SAMPLE No.	ELEV. / DEPTH
	SILT AND CLAY, TRACE OF SAND, BLACK ORGANIC MATERIAL, OLIVE TO GRAY, OCCASIONAL INCLUSIONS OF SILT AND BLACK ORGANIC MATERIAL, FISSURED (CH)		DO	1	
				2	
				3	
				4	
590.6 / 10	SILTY CLAY, TRACE OF SAND, INCLUSIONS OF SILT TO ¼" (CL)	REDDISH BROWN AND BROWN MOTTLED, OCC. PARTICLES OF GRAVEL TO ¼"		5	10
				6	
				7	
		GRAY AND REDDISH BROWN LAYERING CONTORTED		8	
				9	
	SANDY SILT, TRACE OF CLAY, BROWN (ML)			10	20
				11	
570.6 / 30	CLAY & SILT, TRACE OF SAND, REDDISH BROWN, NUMEROUS PARTICLES OF SUB-ANGULAR GRAVEL TO 1", OCCASIONAL ROCK FRAGMENTS TILL (ML-CL)			12	30
	SANDY SILT, TRACE OF CLAY, BROWN, PARTICLES OF GRAVEL TO ¾"	WITH THIN SILT LENSES		13	
					40
		WITH NUMEROUS ROCK FRAGMENTS	LOST	14	
			LOST		50
550.6 / 50	BOTTOM OF HOLE 550				

WATER CONTENT % — w_p · w · w_l — 10 20 30 40 50 60
NATURAL WET DENSITY P.C.F. — 110 120 130 140
SHEAR STRENGTH (P.S.F.) — TYPE: UNCONFINED, QUICK TRIAXIAL, VANE; UNDISTURBED, REMOULDED; STRAIN 15 — 5; 1000 2000 3000 4000
STANDARD PENETRATION TEST BLOWS/FT — 20 40 60 80 100
PARTICLE SIZE % — 20 40 60 80 — CLAY, SILT, SAND, GRAVEL
WATER DROP INS/3 MIN

REMARKS: PENN CENTRAL R.S. LINE BORING 6+7
CHAINAGE RE PENN CENTRAL

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN LMS	GEOTECHNICAL PROFILES
CHECKED J.K	RECOMMENDED C.K. / APPROVED / DATE JUNE 6, 1969 / BORING NO W1219
EXAMINED C.K.	

SLSA 1220

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO W1220
CHAINAGE 27+02 OFFSET 6
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE 591.4 BOTTOM HOLE 521.2
BEDROCK GROUNDWATER

ELEV. / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLER TYPE & SIZE	SAMPLE NO.	ELEV. / DEPTH
	DARK BROWN WITH ORGANIC INCLUSIONS		D.O.	1	
	CLAY AND SILT MOTTLED AND LAYERED, (CONTORTED) WEATHERED			2 3 4 5	10
581.4 10	OLIVE TO BROWN AND REDDISH BROWN, OCCASIONAL SILT LENSES			6	
	BROWN WITH NUMEROUS THIN SILT LAYERS AND INCLUSIONS			7 8 9	20
	INTERBEDDED SILTS, CLAYEY SILTS AND SILTY CLAYS			10	
561.4 30				11	30
	CLAYEY SILT TRACE OF SAND, GREYISH BROWN, OCCASIONAL SUB-ANGULAR GRAVEL TO 1" TILL	ZONE OF LAYERED SILTS (SEEPAGE)		12	40
				13	
541.4 50	BOULDER			14	50
				15	60
	CLAYEY SILT BROWN			16	
	ROCK FRAGMENTS AND SMALL CHUNKS (ANDY SILT (STONY) (RECOVERED ONLY			17	70
519 72.8	BOTTOM OF HOLE 72'				

WATER CONTENT %
10 20 30 40 50 60

NATURAL WET DENSITY P.C.F
110 120 130 140

SHEAR STRENGTH (P.S.F.)
TYPE UNCONFINED ○ UNDISTURBED ● REMOULDED ⊕
QUICK TRIAXIAL ▲ VANE △
1000 2000 3000 4000
STRAIN %

STANDARD PENETRATION TEST BLOWS/FT
20 40 60 80 100

PARTICLE SIZE %
20 40 60 80

WATER DROP INS. / 7 MINS.

ELEV. / DEPTH
10 20 30 40 50 60 70

REMARKS: PLAIN CENTRAL [illegible] INCL. ENGINE = 2
CHAINAGE RE PLAIN CENTRAL

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN	GEOTECHNICAL PROFILES
CHECKED JK	
EXAMINED GJL	RECOMMENDED CF / APPROVED / DATE JUNE 9 1964 / BORING NO W 1220

SLSA 1221

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO W1221
CHAINAGE 30195 OFFSET E
CO-ORDINATES: N
E

ELEVATION
GROUND SURFACE 573.8 BOTTOM HOLE 543.8
BEDROCK GROUNDWATER

ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLER TYPE & SIZE	SAMPLE NO.	ELEV. / DEPTH
	ORGANIC CLAYEY SILT.		D	1	
	SILTY CLAY, WITH NUMEROUS THIN SILT LAYERS AND LENSES; WEATHERED. (CH.CI) — OLIVE GREY MOTTLED			2 3 4 5 6	10
	REDDISH BROWN LAYERED AND MOTTLED OLIVE				
	OLIVE TO GREY REDDISH BROWN MOTTLED.			7 8 9	
553.8 20	CLAYEY SILT, GREY, WITH NUMEROUS THIN SILT LAYERS AND LENSES THROUGHOUT (CI)			10	20
	CLAYEY SILT, TRACE OF SAND; BROWN, OCCASIONAL PARTICLES OF SUB ANGULAR GRAVEL TO 1½" TILL (CL) — WITH OCCASIONAL SILT LAYERS TO ½" THICK		A	11 12	30
533.8 40	CLAYEY SANDY SILT, BROWN OCCASIONAL PARTICLES OF SUB ANGULAR GRAVEL AND ROCK FRAGMENTS TO 1½". TILL (CL)		A	13 LOST 14	40
513.8 60	RECOVERY POOR ROCK FRAGMENTS AND GREY SILTY SAND		A	15	50
	BOTTOM OF HOLE 513.8				60

WATER CONTENT %: w_p — w — w_L; 10 20 30 40 50 60

NATURAL WET DENSITY P.C.F.: 110 120 130 140

SHEAR STRENGTH (P.S.F.): TYPE UNCONFINED ● QUICK TRIAXIAL ○ VANE ×; UNDISTURBED ● REMOULDED ○; 1000 2000 3000 4000; STRAIN IN - %: 0 2 4 6 8 10 12 14 16 18 20

STANDARD PENETRATION TEST BLOWS/FT.: 20 40 60 80 100

PARTICLE SIZE %: 20 40 60 80

WATER DROP (1915 / 2 in.)

REMARKS: PENN CENTRAL R-S LINE BORING B-2

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN LH.M	GEOTECHNICAL PROFILES
CHECKED	
EXAMINED	RECOMMENDED · APPROVED · DATE JUNE 2, 1969 · BORING NO. W1221

TEST BORING NO W1222

PIEZOMETER
TYPE
ELEVATION

CHAINAGE 40+10 OFFSET ℄
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE 545.0 BOTTOM HOLE 5477
BEDROCK GROUNDWATER

ELEV. / DEPTH	DESCRIPTION	STRAT. NOT.	SAMPLER TYPE & SIZE	SAMPLE NO.	ELEV. / DEPTH
	BROWN TO OLIVE MOTTLED,		Dor	1	
	SILTY CLAY, TRACE OF SAND, SILT INCLUSIONS AND PARTINGS, WEATHERED (CH,A)			2	
	LAYERED AND MOTTLED, RED, BROWN AND GREY,			3	
				4	
				5	
	MOTTLED BROWN AND REDDISH BROWN, ZONES OF EARLY SILT			6	20
				7	
				8	
	INTERBEDDED SILTS (BROWN), CLAYEY SILTS (BROWN) AND SILTY CLAYS (REDDISH BROWN TO BROWN) WEATHERED (CL)			9	
525 20				10	25
	WITH OCCASIONAL REDDISH BROWN MOTTLING			11	
	CLAYEY SILT, TRACE OF SAND, GREYISH BROWN, OCCASIONAL LARGE TO SUB-ANGULAR GRAVEL TO COBBLE SIZE TILL (CL-ML)			12	30
				13	
				14	40
	OCCASIONAL SMALL SILT INCLUSIONS, ONE - 1" ZONE BROWN SILT				
5417 473	BOTTOM OF HOLE 473'				50

WATER CONTENT %: w_p — w — w_L; 10 20 30 40 50 60

NATURAL WET DENSITY P.C.F.: 110 120 130 140

SHEAR STRENGTH (P.S.F.): TYPE — UNCONFINED, QUICK TRIAXIAL, VANE; UNDISTURBED; REMOULDED; STRAIN %; 1000 2000 3000 4000

STANDARD PENETRATION TEST BLOWS/FT: 20 40 60 80 100

PARTICLE SIZE %: 20 40 60 80; CLAY, SILT, SAND, GRAVEL

WATER DROP INS/3 MIN.

REMARKS: PENN CENTRAL, R-5 LINE BORING B-4
CHAINAGE 3E PENN CENTRAL

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN	GEOTECHNICAL PROFILES
CHECKED	
EXAMINED	RECOMMENDED / APPROVED / DATE: JUNE 12, 1969 / BORING NO: W1222

SLSA 1223

TEST BORING NO W-1223

PIEZOMETER
TYPE
ELEVATION

CHAINAGE 50+00 OFFSET 4
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE 595.5 BOTTOM HOLE 519.5
BEDROCK GROUNDWATER

ELEV. / DEPTH	DESCRIPTION	STRAT. ROT.	SAMPLER TYPE & SIZE	SAMPLE NO.	ELEV. / DEPTH
	ORGANIC		DO	1	
	SILTY CLAY, TRACE OF SAND, WEATHERED, FISSURED (CH,CI) GREY MOTTLED AND LAYERED (DISTORTED) BROWN AND REDDISH BROWN.			2 3 4 6	
585.5 10				6	10
	BROWN, MOTTLED, FEW SILT PARTINGS			7 8 9	
	BROWN; WITH ZONES SILTS AND CLAYEY SILTS			10	20
	CLAY AND SILT, TRACE OF SAND; GREYISH BROWN, OCCASIONAL FINE GRAVEL, OCCASIONAL THIN SILT LENSES, TILL-LIKE. (CI,CL)			11	
565.5 30					30
				12	40
	CLAYEY SANDY SILT, BROWN, PARTICLES OF SUB-ANGULAR GRAVEL TO 1" TILL (CL)			13	
545.5 50				14	50
				15	60
				16	70
525.5 70	SANDY SILT TRACE OF CLAY, BROWN, PARTICLES SUB ANGULAR GRAVEL AND ROCK FRAGMENTS TO 1" TILL (ML,CL) BOTTOM OF HOLE 76.0'			17	

WATER CONTENT %: W_p — W — W_l; 10 20 30 40 50 60

NATURAL WET DENSITY P.C.F.: 110 120 130 140

SHEAR STRENGTH (P.S.F.) — TYPE: UNCONFINED, QUICK TRIAXIAL, VANE; UNDISTURBED ● ▲; REMOULDED ○ △; STRAIN %: 5 10 15; 1000 2000 3000 4000

STANDARD PENETRATION TEST BLOWS/FT: 20 40 60 80 100

PARTICLE SIZE %: 20 40 60 80; CLAY, SILT, SAND, GRAVEL

WATER DROP INS./2 MIN.

ELEV. / DEPTH

REMARKS: PENN CENTRAL W.C.T. LINE BORING # 5
CHAINAGE RE PENN CENTRAL

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN	GEOTECHNICAL PROFILES
CHECKED	
EXAMINED	RECOMMENDED / APPROVED / DATE / BORING NO.
	JUNE 6, 1961 — W-1223

SLSA 1224

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO W1224
CHAINAGE 60+00 OFFSET ℄
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE 596.2 BOTTOM HOLE 489.2
BEDROCK GROUNDWATER

ELEV. DEPTH	DESCRIPTION	STRAT. PROF.	SAMPLER TYPE & SIZE	SAMPLE NO.	ELEV. DEPTH
	MOTTLED GREY, OLIVE, AND REDDISH BROWN; NUMEROUS THIN LAYERS AND INCLUSIONS SILT			1 2 3 4 5 6 7 8 9	10
	TRACE OF SAND; WEATHERED (CH, CL) OLIVE FAINTLY LAYERED FEW GYPSUM INCLUSIONS				
576.2 20.0	GREY WITH OCC RED LAYERING MOTTLING FEW LAYERS CLAYEY SILT				20
	WITH REDDISH BROWN MOTTLING			10 11 12	30 40
556.2 40.0	CLAYEY SILT, TRACE OF SAND, GREY/BROWN OCCASIONAL PARTICLES OF SUB-ANGULAR GRAVEL TO TILL (CI, CL)			13 14	50
536.2 60.0	RECOVERY POOR BOULDER FRAGMENTS WITH CHUNKS OF THE CLAYEY SILT TILL			15 16 17	60 70
	SILTY AND TRACE OF SAND MOTTLED AND LAYERED (DISTORTED) OLIVE AND GREY INCLUSIONS OF SILT AND CLAYEY SILT (CL)			18 19	80
516.2 80.0	FINE SILTY SAND REDDISH BROWN (SM)			20	90 100
489.2 107	BOTTOM OF HOLE 370				

WATER CONTENT % — w_p ⟷ w ⟷ w_L — 10 20 30 40 50 60
NATURAL WET DENSITY P.C.F. — 110 120 130 140
SHEAR STRENGTH (P.S.F.) — TYPE: UNCONFINED, QUICK-TRIAXIAL, VANE; UNDISTURBED ⊕ ● ▲; REMOULDED ⊖ ○ △; STRAIN 15 ⟷ 5; 1000 2000 3000 4000
STANDARD PENETRATION TEST blows/ft — 20 40 60 80 100
PARTICLE SIZE % — 20 40 60 80
WATER DROP INCH / 3 MIN.

REMARKS: PENN CENTRAL R.S. LINE BORING P.C.
CHAINAGE RE PENN CENTRAL

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN I. Ekl	GEOTECHNICAL PROFILES
CHECKED Y.A.B.	
EXAMINED EJC	RECOMMENDED CHC · APPROVED · DATE JUNE 19, 1969 · BORING NO. W1224

SLSA 1225

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO W1225
CHAINAGE 70+00 OFFSET ℄
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE 597.7 BOTTOM HOLE 513.7
BEDROCK GROUNDWATER

ELEV. / DEPTH	DESCRIPTION
	LAYERED (TO 2') BROWN AND RED FEW LAYERS OF CLAYEY SILT
	SILTY CLAY TRACE OF SAND (CL) BROWN WITH GREY AND REDDISH BROWN LAYERING NUMEROUS THIN LAYERS CLAYEY SILT
597.7 / 20	CLAY AND SILT, TRACE OF SAND, OCCASIONAL BROWN PARTICLES OF SUB-ANGULAR GRAVEL TO 1/4" WEATHERED TILL (CL)
	CLAYEY SILT TRACE OF SAND, GREY BROWN PARTICLES OF GRAVEL AND ROCK (BOULDER) FRAGMENTS TO 1/4" TILL (CL)
597.7 / 40	FINE SANDY SILTS REDDISH BROWN AND BROWN, LENSED AND LAYERED (DISTORTED) (ML)
597.7 / 60	CLAYEY SILT TRACE OF SAND REDDISH BROWN OCCASIONAL PARTICLES SUB-ANGULAR GRAVEL AND ROCK FRAGMENTS TO 1/4" TILL (CL)
	SILTY CLAY, GREY WITH RED LAYERS, FEW SILT PARTINGS (CL)
513.7 / 84	BOTTOM OF HOLE 84.0'

WATER CONTENT %
NATURAL WET DENSITY P.C.F.
SHEAR STRENGTH (P.S.F.) TYPE: UNCONFINED, QUICK-TRIAXIAL, VANE; UNDISTURBED, REMOULDED; STRAIN IS = ε
STANDARD PENETRATION TEST BLOWS/FT
PARTICLE SIZE %
WATER DROP INS/2.45 IN.

REMARKS: PENN CENTRAL, R 3 LINE BORING B-7
CHAINAGE RE PENN CENTRAL

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN	GEOTECHNICAL PROFILES
CHECKED	
EXAMINED	RECOMMENDED / APPROVED / DATE JUNE 12, 1969 / BORING NO W122[illegible]

SLSA 1226

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO W1226
CHAINAGE 75+02 OFFSET ±
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE 579.7 BOTTOM HOLE 579.7
BEDROCK GROUNDWATER

ELEV. / DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLER TYPE & SIZE	SAMPLE NO.	ELEV. / DEPTH
	SAND AND GRAVEL			1	
	SILTY CLAY, TRACE OF SAND, WEATHERED (CL) BROWN TO GREY MOTTLED OLIVE, OCCASIONAL SMALL SILT INCLUSIONS			2	
				3	
				4	
	FAINTLY LAYERED BROWN & GREY			5	10
	CHALEY SILT TRACE OF SAND, BROWN LAMINAL SUB-ANGULAR GRAVEL TILL (CL)			6	
				7	
				8	
	WITH FEW THIN SILT LAYERS			9	
559.7	BOTTOM OF HOLE 20.0				20

WATER CONTENT % — w_p — w — w_L — 10 20 30 40 50 60

NATURAL WET DENSITY P.C.F — 110 120 130 140

SHEAR STRENGTH (P.S.F.) — TYPE: UNCONFINED, QUICK TRIAXIAL, VANE — UNDISTURBED ● ▲ — REMOULDED ⊕ ○ △ — STRAIN % 5 10 15 — 1000 2000 3000 4000

STANDARD PENETRATION TEST BLOWS/FT — 20 40 60 80 100

PARTICLE SIZE % — 20 40 60 80

WATER DROP INS/3 MIN

REMARKS: PENN CENTRAL R.S. LINE BORING 2-H
CHAINAGE RE PENN CENTRAL

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN	GEOTECHNICAL PROFILES
CHECKED	
EXAMINED	

RECOMMENDED	APPROVED	DATE	BORING NO
		JUNE 12 1964	W1226

SLSA 1227

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO W 1227'
CHAINAGE 82+20 OFFSET 6
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE 578.7 BOTTOM HOLE
BEDROCK GROUNDWATER

ELEV. DEPTH	DESCRIPTION	STRAT PLOT	SAMPLER TYPE & SIZE	SAMPLE No.	ELEV. DEPTH
	BROWN MOTTLED OCCASIONAL SILT INCLUSIONS		DO	1	
	CLAY AND SILT, TRACE OF SAND, OCCASIONAL FINE GRAVEL (CL)			2	
	REDDISH BROWN NUMEROUS LENSES AND LAYERS SILT.			3	
				4	
				5	10
				6	
				7	
				8	
579.7 2.0	ZONE OF CLAY & SILT GREY TO BROWN, SILT INCLUSIONS & PARTINGS			9	20
	WITH ZONES TO 6' OF BROWN SILT (DENSE)			10	
	CLAYEY SILT, TRACE OF SAND, GREYISH BROWN, OCCASIONAL PARTICLES OF SUB ANGULAR GRAVEL AND ROCK (BOULDER) FRAGMENTS TO 1½' TILL. (Cl CL, ML CL ML)			11	30
538.7 40				12	40
	POSSIBILITY OF A SANDY ZONE			13	
				14	50
				15	
518.7 60				16	60
	CLAY AND SILT TRACE OF SAND & GREYISH BROWN FEW THIN LAYERS BROWN CLAYEY SILT (CL)			17	
	SILTY CLAY, REDDISH BROWN, MOTTLED OR LAYERED GREY, FEW SILT LENSES & PARTINGS (CL)			18	
500.2 78.5	BOTTOM OF HOLE 78.5'				

WATER CONTENT %
NATURAL WET DENSITY P.C.F.
SHEAR STRENGTH (P.S.F.) TYPE UNCONFINED QUICK TRIAXIAL VANE; UNDISTURBED; REMOULDED; STRAIN %
STANDARD PENETRATION TEST BLOWS/FT
PARTICLE SIZE %
WATER DROP (in 1/2 min.)

REMARKS: PENN CENTRAL RLY RELOCATION BORING 64
CHAINAGE RE PENN CNTRAL

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN S.M.P.A.	GEOTECHNICAL PROFILES
CHECKED J.K.	
EXAMINED C.R.	RECOMMENDED J.S.R. / APPROVED / DATE JUNE 5, 1969 / BORING NO W 1227

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO

CHAINAGE OFFSET
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE BOTTOM HOLE
BEDROCK GROUNDWATER

ELEV. DEPTH	DESCRIPTION	STRAT PLOT	SAMPLER TYPE & SIZE	SAMPLE No.	ELEV. DEPTH
	PEAT ORGANIC			1	
	SILTY CLAY TRACE OF SAND BROWN OCCASIONAL FINE SAND SEAMS AND NUMEROUS THIN SILT PARTINGS AND LENSES (CL)			2	
	WITH FEW SILT PARTINGS			3	
	SILTY CLAY AND SILT LAMINATED BROWN ALTERNATE SILT AND CLAY LAYERS AIR DRIED AND WEATHERED FISSURED TILL			4	
				5	
				6	
				7	
				8	
	WITH THIN SILT LENTICULAR BEDDING			9	
				10	
	SILTY CLAY LAMINATED GREY BROWN DRIED OCCASIONAL SILT SEAMS AND INCLUSIONS (CL)				
	WITH FEW THIN LAYERS OF SILT			11	
	GREY SILTY FINE SAND TRACE OF CLAY BROWN ORGANIC LAMINAL PARTICLES OF ANGULAR GRAVEL AND STONE FRAGMENTS (SM)			12	
				13	
				14	
				15	
				16	

WATER CONTENT %
W_p W W_L
10 20 30 40 50 60

NATURAL WET DENSITY P.C.F
110 120 130 140

SHEAR STRENGTH (P.S.F.)
TYPE — UNDISTURBED — REMOULDED
UNCONFINED ⊕ ⊖
QUICK TRIAXIAL ● ○
VANE ▲ △
STRAIN IS = 5
1000 2000 3000 4000

STANDARD PENETRATION TEST
BLOWS/FT
20 40 60 80 100

PARTICLE SIZE %
20 40 60 80

WATER DROP IN 1/2 MIN

REMARKS:

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN	GEOTECHNICAL PROFILES
CHECKED	
EXAMINED	RECOMMENDED / APPROVED / DATE / BORING NO

Observation Well 2010

TEST BORING NO W1169 & W1169A

PIEZOMETER
TYPE
ELEVATION

CHAINAGE OFFSET
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE 583.3 BOTTOM HOLE 447.0
BEDROCK 457.6 GROUNDWATER

ELEV. DEPTH	DESCRIPTION	STRAT PLOT	SAMPLER TYPE & SIZE	SAMPLE No.	ELEV. DEPTH
583.3 0	OLIVE TO REDDISH BROWN; THIN SILT LAYERS		D3	1	10
	REDDISH BROWN, LAYERING BROWN & GREY, WEATHERED		CO	2	
	SILTY CLAY (CH, CI, CL)		CO	3	20
563.3 20	GREY WITH REDDISH BROWN LAYERING AND MOTTLING, WITH SILT ZONES TO 1"		D3	4	30
			D3	5	
	CLAYEY SILT, TRACE OF SAND, BROWN OCCASIONAL PARTICLES, SUB-ROUNDED GRAVEL, TO 4" TILL (CL)		D3	6	40
543.3 40	SILTY CLAY, BROWN, WITH REDDISH BROWN OR GREY LAYERING OR MOTTLING (CL,CI) WITH FEW SILT INCLUSIONS		D3	7	
	WITH NUMEROUS CLAYEY SILT ZONES AND INCLUSIONS.		D3	8	50
			D3	9	
523.3 60	CLAYEY SILT, TRACE OF SAND, BROWN, PARTICLES SUB-ANGULAR GRAVEL TO 1" TILL (ML-CL)		CO	10	60
	BOULDERS		CK	11	
			LS	12	70
	SAND AND BOULDERS				80
493.3 90					90
					100
					110
457.6 125.7	TOP OF BEDROCK 125.7		W/T		120
	BOTTOM OF HOLE 138.6				130
					140

WATER CONTENT % — w_p ⊢ w ⊣ w_l — 10 20 30 40 50 60

NATURAL WET DENSITY P.C.F. — 110 120 130 140

SHEAR STRENGTH (P.S.F.) — TYPE: UNCONFINED, QUICK TRIAXIAL, VANE — UNDISTURBED ● ▲ — REMOULDED ⊗ △ — STRAIN IS 0 5 10 — 1000 2000 3000 4000

STANDARD PENETRATION TEST BLOWS/FT — 20 40 60 80 100

PARTICLE SIZE % — 30 40 60 80 — SAND — SILT

WATER DROP INST 2 MIN.

REMARKS:
LIMITED SIEVE ANALYSIS NOS 2 & 7 & 8 DONE ON CLAYEY SILT PORTION.
NO REPRESENTATIVE OF CONTACT SAMPLE

REMARKS: RE OBSERVATION WELL NO 10
LOCATION SOUTH SIDE OF BIGGAR RD 200' E OF YOUNG RD

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY
PREPARED	WELLAND CHANNEL RELOCATION
DRAWN	GEOTECHNICAL PROFILES
CHECKED J.K	
EXAMINED	RECOMMENDED / APPROVED / DATE Dec 23/68 / BORING NO W1169 W1169A

8.5 SUPPORTING CALCULATIONS AND METHODS

In 1856, the French hydraulics engineer Henry Darcy reported that flow through a porous medium is proportional to the head loss and inversely proportional to the distance travelled. The formulation of these relationships is called Darcy's Law and may be written as; specific discharge (v) = hydraulic conductivity (K) x gradient (i). The specific discharge is the total discharge per unit area of the discharging porous medium and does not indicate the velocity of the water 'particles'. The velocity of the water (average linear velocity, v) may be obtained by dividing the specific discharge (v) by the effective porosity (n) of the porous medium. Because effective porosity is always less than 1, the average linear velocity (v) is always greater than the specific discharge (v).

$$\text{Average Linear Velocity (v)} = \frac{\text{hydraulic conductivity (K) x gradient (i)}}{\text{effective porosity (n)}}$$

Once the above parameters are known for a porous medium, an average linear velocity may be calculated. The following example utilizes values typical of lateral flow in the fractured zone:

Lateral Ground Water Flow

- hydraulic conductivity (K)	1×10^{-8} m/s
- lateral gradient (i)	0.003
- effective fracture porosity (n)	0.0001

$$\bar{v} = \frac{Ki}{n} = \frac{1 \times 10^{-8} \times 0.003}{0.0001} = 3 \times 10^{-7} \text{ m/s or } \sim 9.5 \text{ m/year}$$

Vertical Ground Water Flow

The application of Darcy's Law to ground water flow through layered porous media when the layers have differing thicknesses and hydraulic properties is discussed in Freeze and Cherry (1979) summarized below with regard to the area under study. The layered porous media of interest are the confining layer subunits which usually include the fractured zone, the unfractured zone, and the lower till. Estimating the rates of ground water flow in each of these layers involves (1) the calculation of a single equivalent hydraulic conductivity for the three layers, (2) calculation of the specific discharge through the layers, and (3) the calculation of average linear velocities in each of the layers.

The calculation of an equivalent hydraulic conductivity (Ke) for the three-layer situation is:

$$Ke = \frac{d(FCL + CL + LT)}{\frac{dFCL}{KFCL} + \frac{dCL}{KCL} + \frac{dLT}{KLT}}$$

where K and d are the hydraulic conductivity and thickness respectively and the subscripts are 'e' (equivalent), 'FCL' (fractured confining layer), 'CL' (confining layer) and LT (lower till).

The calculation of specific discharge (v) uses the equivalent hydraulic conductivity (Ke) and the overall vertical gradient (i) across the layers in Darcy's Law

$$v = Ki$$

And finally, the average linear ground water velocity ($\bar{v}$) in each layer is obtained by dividing the specific discharge (v) by the effective porosity (n) for each of the layers involved.

The following example uses numbers similar to those in the report (values relate to the layers identified above; thicknesses are in m and hydraulic conductivities are in m/s).

$$Ke = \frac{27.1}{\frac{3.7}{1x10^{-8}} + \frac{18.4}{3x10^{-10}} + \frac{5.0}{1x10^{-8}}} = \frac{27.1}{6.2x10^{-10}} = 4.4x10^{-10} \text{ m/s}$$

where the vertical gradient (i) is 0.3:

$v = Kei = 4.4x10^{-10} \times 0.3 = 1.3x10^{-10}$ m/s

The average linear velocity ($\bar{v}$) = specific discharge divided by the effective porosity for each individual layer.

For the fractured confining layer, effective porosity (n) = 0.0001 and the average linear velocity ($\bar{v}$) =

$1.3x10^{-10}/0.0001 = 1.3x10^{-6}$ m/s or ~41 m/year.

For the unfractured confining layer (glaciolacustrine units, Halton Till), no effective porosity value is available and consequently a total porosity value of 0.5 is used to calculate an average linear velocity ($\bar{v}$):

$1.3x10^{-10} / 0.05 = 2.6x10^{-10}$ m/s
or $8.2x10^{-3}$ m/year.

For the lower till, no effective porosity value is available and consequently a total porosity value of 0.3 is used to calculate an average linear velocity:

$$1.3 \times 10^{-10} / 0.3 = 4.3 \times 10^{-10} \text{ m/s}$$

$$\text{or } 1.4 \times 10^{-2} \text{ m/year.}$$

(These are approximate values and are usually rounded to one significant figure in the text).

The major assumptions for these calculations are:

(1) flow is steady state,
(2) flow is in a direction perpendicular to the layering,
(3) layers are homogeneous and isotropic,
(4) flow is governed by Darcy's Law. A more complete and theoretical discussion is given in Freeze and Cherry (1979).

For a more detailed discussion of ground water flow rates through the confining layer based on advection and diffusion calculations, the reader is referred to Appendix A of the report entitled "Site Selection Process; Phase 4A, Selection of Preferred Site(s), Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

8.6 GLOSSARY OF SELECTED TERMS

Sources are provided at the rear of this section and are referenced by the bracketed number following each definition.

Some definitions are altered slightly to reflect useage in this report and may not reflect the wide range of meanings provided in the source.

8.6 GLOSSARY OF SELECTED TERMS

Alluvium
Sediment composed of organic material, clay, silt, sand, gravel cobbles, or boulders deposited by postglacial streams. (2)

Aquifer
A body of sediment (or rock) that contains sufficient saturated permeable material to conduct ground water and yield economically significant quantities of ground water to wells and springs.(2)

Bearing Pressure (Allowable)
Means the maximum pressure that may be safely applied to a soil or rock by the foundation unit in design under expected loading and subsurface conditions. (8)

Confining Bed (Layer)
A body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers. (1)

Darcy's Law
For the velocity of percolation of water in saturated soil: Velocity = coefficient of permeability x hydraulic gradient. (4) (hydraulic conductivity is used in place of coefficient of permeability in this report).

Desiccated Crust
The exposure of fine-grained sediments to drying is accompanied by shrinkage and possibly cracking. Precompression of the upper portions of clay layers by drying is frequently observed in many of the profiles encountered in practice. The effects of desiccation are an increase in strength and a decreased water content. (6)

Drawdown
The lowering of the water level in a well as a result of withdrawal. (1)

Drift
A general term applied to all rock material (clay, silt, sand, gravel, boulders) transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier. (1)

Evaporite
A nonclastic sedimentary rock composed primarily of minerals produced from a saline solution as a result of extensive or total evaporation of the solvent. Examples include: gypsum, anhydrite, rock salt, primary dolomite, and various nitrates and borates. (3)

Geometric Mean
The nth root of the product of the values of n positive numbers; the antilogarithm of the mean of the logarithms of individual values. (1)

Geotechnical, Geotechnics
Pertaining to the broad field of geotechnics. The application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust for the solution of engineering problems. (1)

Glacial Lake
A lake fed predominantly by glacial meltwater or a lake in a depression in part closed by glacial ice. Includes lakes not directly adjacent to the glacier and lakes lying against or on a glacier, and fed mainly by waters derived from the melting of a glacier. (2)

Glaciofluvial
Pertaining to streams flowing from glaciers or to the deposits made by the streams. (2)

Glaciolacustrine
Pertaining to or characterized by glacial and lacustrine (lake) conditions. Material deposited in lakes affected by glacier ice, or deposited by meltwater flowing directly from glaciers into a lake. (2)

Ground Water
Subsurface water occurring below the water table (phreatic surface) in the saturated zone in which all pores are filled with water under hydrostatic pressure. This contrasts with subsurface water above the water table, which is referred to as soil moisture. (2)

Grout
A cement slurry of high water content, fluid enough to be poured or injected into spaces and thereby fill or seal them. (1)

Hardness (Water)
A property of water causing formation of an insoluble residue when the water is used with soap, and forming a scale in vessels in which water has been allowed to evaporate. It is primarily due to the presence of ions of calcium and magnesium, but also to ions of other alkali metals, other metals (e.g. iron), and even hydrogen. Hardness of water is generally expressed as parts per million as $CaCO_3$ (40 ppm Ca produces a hardness of 100 ppm as $CaCO_3$); also as milligrams per litre, and is the combination of carbonate hardness and noncarbonate hardness. (1)

Hazardous Waste
Waste that poses a present or potential danger to human beings or other organisms because it is toxic, flammable, radioactive, explosive, or has some other property that produces substantial risk to life. (1) (Use here excludes radioactive waste)

Heave
A predominantly upward movement of a surface, caused by expansion or displacement, as from swelling clay, removal of overburden, seepage pressure, or frost action. (1)

Hydraulic Gradient
In an aquifer, the rate of change of total head per unit of distance of flow at a given point and in a given direction. (1)

Hydraulic Head
The height of the free surface of a body of water above a given subsurface point. (1)

Hydraulic conductivity
The proportionality factor in Darcy's law as applied to the viscous flow of water in soil, that is, the flux of water per unit gradient of hydraulic potential. (3)

Hydrogeology
The science that deals with subsurface waters and with related geologic aspects of surface waters. (1)

Hydrostratigraphic Unit
A term proposed by Maxey (1964, p. 126) for a body of rock having considerable lateral extent and composing "a geologic framework for a reasonably distinct hydrologic system". (1) (used here for soil and rock).

Infiltration
The flow of a fluid into a solid substance through pores or small openings; specifically the movement of water into soil or porous rock. (1)

Lamina
The thinnest recognizable unit layer of original deposition in a sediment or sedimentary rock, differing from other layers in colour, composition, or particle size; specifically such a sedimentary layer less than 1 cm in thickness (commonly 0.05-1.00 mm thick). (1)

Log
A continuous record as a function of depth, usually graphic and plotted to scale on a narrow paper strip, of observations made on the rocks and fluids of the geologic section exposed in a well bore. (1) (used here for soil and rock).

Moraine
Accumulation of glacial material (mainly till) deposited by glaciers. (2)

Particle Size Classification System (9)

Name	Qualifying Term	Approximate Particle Size (mm)
Boulders		<200
Cobbles		60-200
Gravel	(Pebble)	2-60
Sand	Coarse	0.6-2
	Medium	0.2-0.6
	Fine	0.06-0.2
Silt		0.002-0.06
Clay		<0.002

Permeability
The capacity of a porous medium to transmit a liquid or gas subjected to an energy gradient (in the case of water, hydraulic gradient). (2)

Porosity
The ratio of the volume of voids to the total volume of a soil sample. (4). Effective porosity is the amount of interconnected space available for fluid transmission (3).

Quaternary
The youngest period of the two geologic time divisions of the Cenozoic Era. The Quaternary is subdivided into the Pleistocene and Recent (or Holocene) Epochs. It comprises all geologic time and deposits from the end of the Tertiary (approximately 2 million years ago) until and including the present. (2)

Saturated
Said of the condition in which the interstices of a material are filled with a liquid, usually water. It applies whether the liquid is under greater than or less than atmospheric pressure, so long as all connected interstices are full. (1)

Settlement
Downward movement of a structure such as a railway bridge, dam, or building, due to compression or movement of the soil below it. (4)

Shear Strength
The internal resistance offered to shear stress. It is measured by the maximum shear stress, based on original area of cross-section, that can be sustained without failure. (5)

Two extreme conditions may be recognized: drained conditions, under which the changes in stress are applied so slowly with respect to the ability of the soil to drain that no excess pore pressures develop, and undrained conditions, under which the stresses are changed so rapidly with respect to the ability of the soil to drain that no dissipation of pore pressure takes place. (7)

Slug Test
A method of determining in situ hydraulic conductivity in a single piezometer by causing an instantaneous change in the water level by adding or displacing a known volume of water. (10)

Split Spoon Sampler
Sampling spoons for exploratory borings commonly consist of a pipe with an inside diameter of about 35 mm and an outside diameter of about 51 mm. The pipe is split lengthwise. Consequently the sampler is called a split spoon. While the sample is being taken, the two halves of the spoon are held togther at the ends by short pieces of threaded pipe. One piece serves to couple the spoon to the wash pipe. The other, which has been sharpened, serves as the cutting edge while the spoon is driven into the soil. Exact dimensions are designated in ASTM DI586-67. (7)

Static (Water) Level
That water level of a well that is not being affected by withdrawal of ground water. (1)

Stratigraphic Unit
A stratum or body of adjacent strata recognized as a unit in the classification of a rock sequence with respect to any of the many characters, properties, or attributes that rocks may possess. (1)

Surcharge Load
A weight per unit of area of fill great enough to consolidate the soil sufficiently to increase its strength or reduce its compressibility to the required extent within the time available. Compressible soils such as clays, loose silts, and most organic soils may be compacted by surcharging. (7)

Till
An unsorted mixture of clay, silt, sand, pebbles, cobbles and boulders deposited directly by glacier ice. (2)

Water Table
A surface in the saturated zone below ground level along which the hydrostatic pressure is in equilibrium with the atmospheric pressure. (2)

Weathering
The destructive process or group of processes by which earthy and rocky materials on exposure to atmospheric agents at or near the earth's surface are changed in colour, texture, composition, firmness, or form with little or no transport of the loosened or altered material; specifically, the physical desintegration and chemical decomposition of rock that produce an in situ mantle of waste and prepare sediments for transportion. (1)

SOURCES

(1) Glossary of Geology (Second Edition); R.L. Bates and J.A. Jackson; American Geological Institute, Falls Church, Virginia, 1980.

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(6) Fundamentals of Soil Behaviour; J.K. Mitchell; John Wiley and Sons Inc., 1976.

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8.7 DETAILED FIELD METHODS

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8.7.1. INTRODUCTION

Field data for of the Phase 4A hydrogeologic onsite investigations were collected in a standardized fashion and formed part of the basis for geologic, hydrogeologic, and geotechnical comparisons of the eight candidate sites. An outline of the major field activities is shown in Figure 9. The study approach was modified only slightly on a site-by-site basis to accommodate differing circumstances and site conditions. Standard procedures for the drilling and sampling operations, as outlined in the Gartner Lee Associates Ltd. "Drilling and Sampling Protocol" document (GLAL 1984a), were adhered to throughout the drilling program. This protocol document provides examples of field forms used to document field activities and should be referred to for more detailed drilling and sampling procedural descriptions.

8.7.2. DRILL SITE IDENTIFICATION

8.7.2.1 Preliminary data analysis

A preliminary review of existing water well and test hole data was completed to establish a basis for the selection of tentative drill locations. Criteria used included the following:

- the distribution of existing test holes and water wells;
- the continuity of existing data; and
- anomalous or unusual site conditions.

While locations were selected primarily on technical grounds, practical considerations such as site access, potential crop damage, and landownership were also taken into account.

DETAILED FIELD METHODS

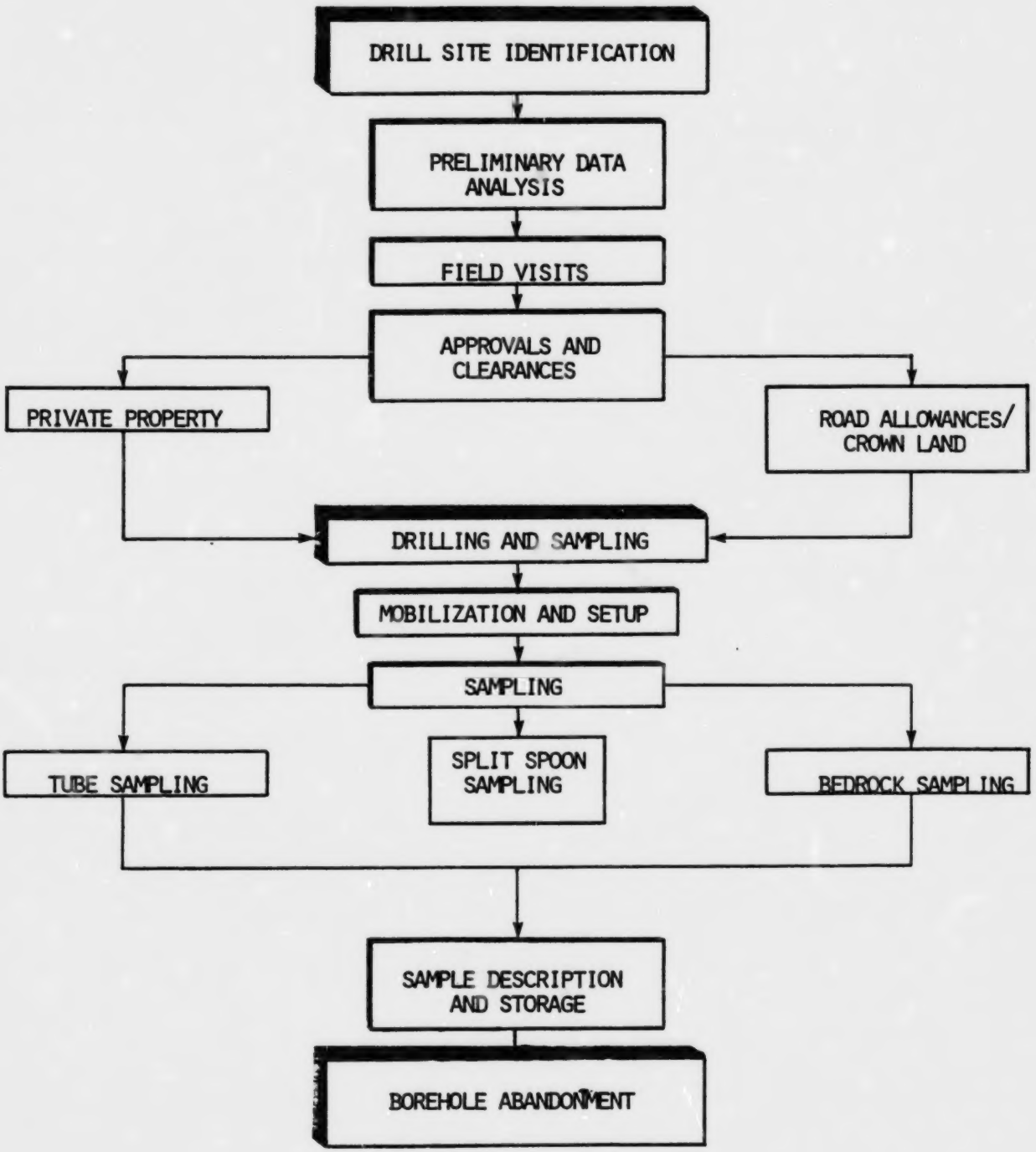

Figure 9

8.7.2.2 Field visits

The concerns of local public interest groups and individuals were also considered in selecting drill locations. Local interest groups were invited to participate during field checking of the drill locations. During these field visits, additional data on water use, local soil conditions, and wells were obtained from local residents. This information was used as a check on some of the field data obtained previously by Ecolgistics Limited during the 1984 "Walk and Talk" survey. The amount of information thus obtained varied from site-to-site and depended largely upon the degree of co-operation given by residents and landowners.

A limited amount of soil probing was completed at Candidate Sites LF-3C, LF-9C, and PI-13N using a 25 mm (1 inch) magnesium hand auger. These investigations were generally limited to a depth of 1 to 2 m. Hand augering was directed toward areas of suspected granular soils or anomalous soil conditions identified by local residents. Soil probing was confined to areas where property access was permitted. Soil descriptions are included under "Field Station Descriptions" in the individual technical site reports.

The tentative drill locations were adjusted during the field visits to avoid difficult or unsafe drilling locations. Each location was marked with a temporary wooden stake. Final adjustments were subsequently made, where necessary, to provide the required safe setbacks from buried and overhead services.

8.7.2.3 Approvals and Clearances

Clearances for both road allowances and adjacent private

or public property were pursued where identified drilling locations were located in the vicinity of local roads. Road allowances were drilled where access to private property was denied.

Landowners and tenants of affected properties were initially contacted by GLAL and verbal approval for test drilling was obtained. Approval was confirmed with a follow up letter from OWMC. For road allowance clearances, the appropriate agencies were contacted and the necessary permit approvals were obtained.

Utilities were contacted and buried service cables and/or pipes were field located by utility personnel and final adjustments of drill locations were completed. Drilling approvals and clearances were completed on a site-by-site basis.

8.7.3 DRILLING AND SAMPLING

8.7.3.1 Drilling equipment and setup

All Terrain Drilling Limited was retained to provide drilling services. The drilling equipment included truck and track mounted CME 75 auger drilling rigs. Two rigs were used simultaneously for most of the drilling program. Each rig was equipped to drill and sample both soils and bedrock. Each rig was staffed with a three man drilling crew and supervised by a GLAL geologist. The drilling program was initiated on August 13, 1984 at Site LF-3C and was completed on November 22, 1984 at Site LF-4N.

The drill rigs were set up in accordance with standard drilling practices and in a manner that allowed the safe

and efficient operation of the equipment. A safety corridor was roped-off around the drill rig to limit access to the rigs. Access to the roped-off area was restricted to individuals with proper safety equipment which included steel-toed boots and a hard hat. A record was kept of all visitors to the drill site as well as persons entering the roped-off area.

Sample documentation and storage facilities were set up at the edge of the roped-off area by GLAL. Soil and rock samples were accessible to the general public for viewing and/or photographing as the samples were being logged by the onsite geologists. Samples were subsequently sealed in tubes or core boxes, labelled, and placed in storage. On several occasions, soil sample tubes were re-opened for examination at the request of local residents.

8.7.3.2 Soil sampling

The drilling program was designed to obtain a continuous column of soil from the ground surface to and including the upper few metres of the underlying bedrock. Soil samples were obtained using hollow stem auger drilling techniques. Hollow stem augers (108 mm (4.25 inch) inside diameter) were used throughout the drilling program.

Split tube sampling. Tube samples measuring approximately 89 mm (3.5 inches) in diameter by 1.52 m (5 ft.) in length were taken continuously from ground level to the bedrock surface. The tube sampler consisted of a split tube with a bevelled sampler tip. The split tube was threaded at both ends and fastened to the drill rods as shown in Figure 10. The sampler as advanced inside the hollow stem augers with

Continuous Soil Sampling With Split Tube Sampler

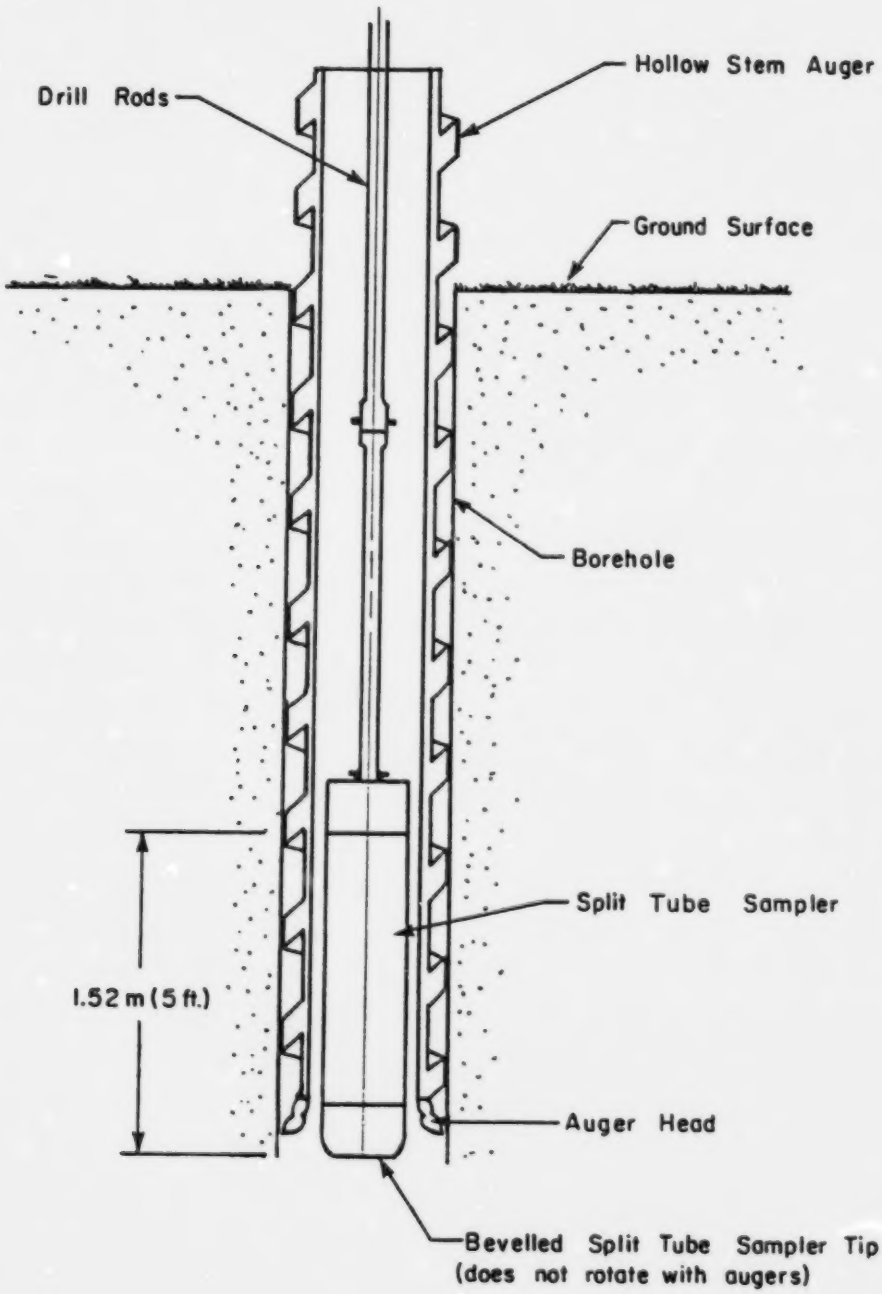

Figure 10

the bevelled tip slightly ahead of the cutting edge of the augers. A split tube sample was obtained by advancing the sampler with the rotating augers. The augers and sampler were advanced at about 1.52 m (5 ft.) intervals or until refusal, and the sampler was then withdrawn from the borehole. The soil sample was removed from the tube and the sampler washed with clean water. Sample recovery for the tube samples was generally between 90 to 100% and was recorded in the field log. Difficult drilling conditions or large cobbles occasionally resulted in lower sample recovery.

Split spoon sampling. Standard split spoon samples were taken at about 1.52 m (5 ft.) intervals throughout the soil sequence overlying bedrock and beginning at about 1.52 m 5 ft.) from the ground surface. Sample intervals are shown schematically in Figure 11.

The split spoon sampler was driven by dropping a 63.5 kg (140 lb.) weight a distance of about 750 mm (30 inches). The sampler was inserted inside the hollow stem augers in a similar fashion to the tube sampler. It was then driven into the soil below the bottom of the augers a distance of about 460 mm (18 inches) or until refusal. The number of blows required to advance the sample for each interval of about 150 mm (6 inches) was recorded in the field log. The split spoon was usually withdrawn when 50 or more blows were required to advance the sampler approximately 150 mm (6 inches) into the subsoil.

Standard split spoon samples were obtained in place of tube samples where difficult drilling conditions were

Soil & Rock Sample Intervals, Phase 4A Drilling Program

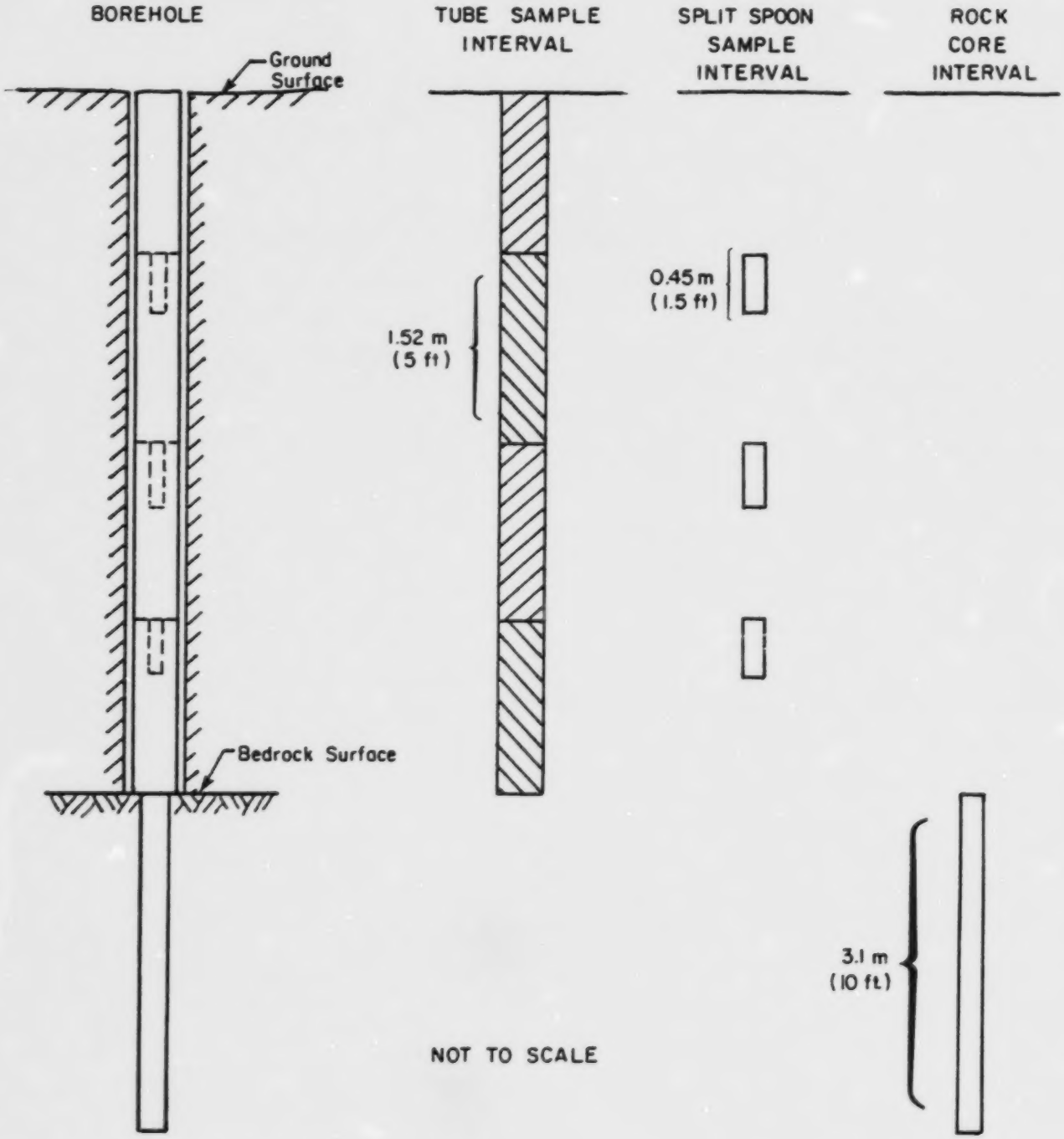

Figure 11

encountered. At Site LF-4N, Borehole 4, granular soils were encountered at a depth of about 30 m (100 ft.) causing refusal of the tube sampler. Standard split spoon samples were taken from a depth of 30 m (100 ft.) at intervals of 0.5 to 3 m (1.6 to 9.8 ft.) to a depth of about 40 m (130 ft.). Difficult soil conditions were also encountered at Site LF-2N, Borehole 1. Numerous rock fragments were encountered below a depth of about 12 m (40 ft.) at this location. Split spoon samples at 0.76 m (2.5 ft.) intervals were taken between depths of about 12 m (40 ft.) to 34 m (110 ft.).

Difficult (sandy and gravelly) soil conditions at Site PI-27E, Borehole 3 prevented tube sampling between depths of about 16 to 30 m (50 to 100 ft.). Similar fine, sandy soils were also encountered in Borehole 4 at this site at depths between approximately 24 to 30 m (80 to 100 ft.). Standard split spoon samples at 1.5 m (5 ft.) intervals were collected over these intervals at these two borehole locations.

Moisture tin samples. A small soil sample of approximately 100 grams was taken from the tip of each split spoon sample for laboratory determination of the soil moisture content. Soil moisture samples were placed in air tight tins immediately after they were taken from the split spoon samples. The moisture tin (sample) numbers were recorded on the field borehole logs. The samples were temporarily stored in the field and shipped in batches to the GLAL office for transfer to a commercial laboratory.

Rotary drilling. Rotary drilling techniques were occas-

ionally used to penetrate difficult soils that could not readily be drilled with conventional hollow stem auger drilling methods. These techniques were also used where granular soils, acting under hydraulic pressures, were forced up inside the hollow stem augers. This condition prevented the split tube and split spoon samplers from passing through the plugged portions of the hollow stem augers. Clean water or a water/bentonite mixture was circulated through a rotating tricone drill bit to clean out the material in the hollow stem augers. Rotary drilling was also used to drill through gravelly or bouldery soils such as those encountered at depth at Site LF-4N, Borehole 4, and at Site LF-2N, Borehole 1.

8.7.3.3 Bedrock sampling

Boreholes were generally completed into bedrock except in a few cases where difficult drilling conditions were encountered and the borehole was terminated before reaching bedrock.

The bedrock contact was often obscured as a result of weathering, particularly in shale. Under conditions of extreme weathering, shale was occasionally retrieved within the split tube and split spoon samplers. For example, a nearly complete 1.5 m core of weathered bedrock was obtained in the split tube sampler in Borehole 5 at Site PI-13N.

Diamond drill coring. Most bedrock samples were obtained using a diamond drill bit and NX size core barrel. Rock core samples generally measured about 53 mm (2.1 inches) in diameter and up to 3 m (10 ft.) in length. The diamond drill bit and core barrel were positioned on the bedrock

surface from inside the hollow stem augers. A rock core was obtained by the cutting action of the rotating drill bit. Clean water was circulated in the borehole to remove cuttings from around the drill bit. The water used in this operation was field checked with a Hach Kit for chlorides and sulphates to ensure compatibility with grouting materials used for borehole abandonment. The amount of water used was recorded on the field logs.

Bedrock coring was terminated when a sufficient length of sample was retrieved to prove-out the bedrock contact. The bedrock core recovered varied in length from about 1.5 m to 3 m (5-10 ft.) between borehole locations.

8.7.3.4 Sample description and storage

Soil and rock samples, taken from the boreholes, were described in detail in the field and photographed. Sample descriptions were recorded on the Field Borehole Log forms. These logs, together with the sample photos, form a permanent record of the sampling procedures.

The tube samples were transferred directly from the sampler into PVC tubular piping which was cut in half. The PVC pipe measures 89 mm (3.5 in.) inside diameter by 1.5 m (5 ft.) long. One 'side' of the sample was scraped clean along its length with a knife or spatula to facilitate sample description. Individuals and local interest groups were allowed to view the samples and make their own field notes of the samples. Soil scrapings were given to those interest groups that requested them or else were discarded. Soil samples were sealed in the PVC tubes by covering the

ends with plastic caps and taping the entire tube along the seams. Sample labels were affixed to each PVC tube.

The samples were stored temporarily in a field van until a sufficient number of samples were obtained for transport to permanent storage facilities in Toronto at the Ontario Geological Survey. Each shipment of samples were itemized on a Sample Packing list. The contents of each shipment were also recorded on a Chain of Custody Record which showed the times and dates of sample transfer as well as the individuals involved in handling the samples.

Split spoon soil samples taken during the project were described in the field and soil moisture (moisture tin) samples taken from the base of the split spoon sampler were submitted to a laboratory for analysis. The moisture tin number was recorded on the Field Borehole Log and on the Sample Packing List. In cases where a split spoon sample was taken in place of the larger split tube samples, they were stored in labelled plastic bags and retained with the other samples. The top of each bedrock core segment was marked on both the core boxes and on the rock core itself with a felt marker.

The soil and rock samples were re-examined by a senior GLAL geologist at the permanent storage area at the Ontario Geological Survey. The field descriptions were combined with the more detailed geologic log prepared by the senior geologist to compile a final borehole log. All soil samples were resealed after examination.

8.7.4 BOREHOLE ABANDONMENT

Boreholes were generally terminated after pentrating the bedrock or when difficult conditions prevented further drilling. An exception to this occurred at Site LF-1E, Borehole 3, where a gas pocket was encountered at a depth of about 17.8 m (58 ft.) in the drift. The borehole was terminated at this depth and sealed as soon as the gas pressure subsided sufficiently to allow grouting.

8.7.4.1 Grouting

On completion of each borehole all sampling equipment and temporary casing were removed from the borehole. Each borehole was then filled to the surface with a cement/ bentonite slurry. This was accomplished by injecting grout through the hollow stem augers as they were slowly withdrawn from the hole as shown in Figure 12. Specifications of the slurry mix, as set out in the Drilling and Sampling Protocol Document (GLAL 1984a) were altered slightly to accommodate site conditions. The actual grout slurry mix is compared on a percent weight basis to the specified grout slurry mix below:

Specified Grout Slurry	Actual Grout Slurry
1.2% Bentonite	2-3% Bentonite
6.0% Hydrated Lime (optional)	
59.6% Cement (Portland Type 10)	40-60% Cement (Portland Type 10)
33.2% Water	37-58% Water

The increased amount of bentonite provides a more effective seal in water bearing formations. The bentonite also acts as a 'plasticizing' agent and eliminated the need

Grouting Of Borehole

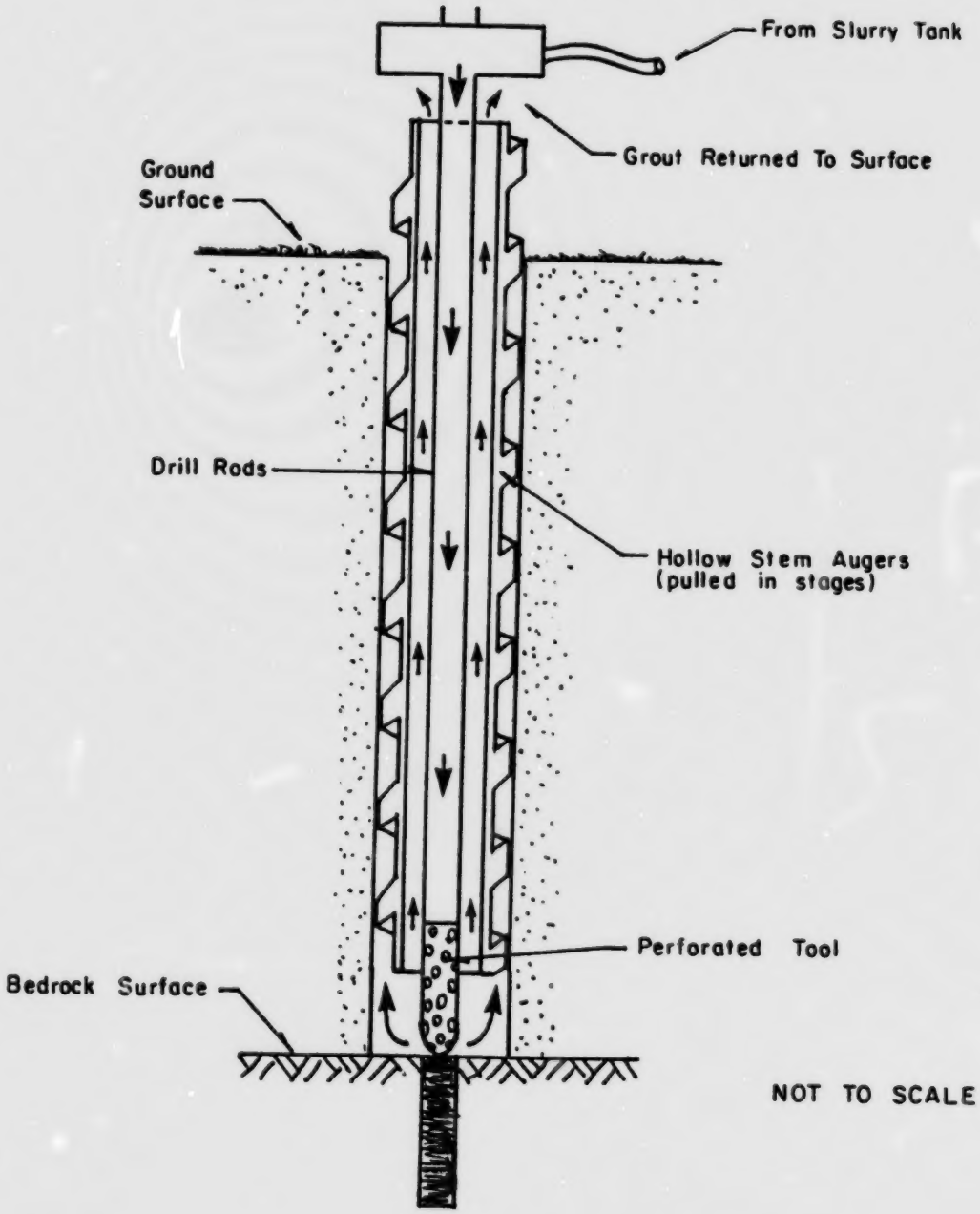

Figure 12

to add hydrated lime to the grout slurry mix. A cement mix containing slightly less than the amount of cement specified in the protocol was found to be adequate. A small sample of grout slurry was taken from each hole to confirm the setting characteristics of the mix.

The water used in the grout slurry was obtained locally and was tested wth a Hach Kit for sulphate and chloride content. Details of each grout mix were recorded on the Borehole Plugging Plan/Record for each borehole.

The grout was allowed to set overnight and generally settled to within 1 to 3 m (3-10 ft.) of ground surface. The hole was subsequently backfilled to grade with soil to avoid interference with surface activities such as ploughing or maintenance along road allowances. All boreholes from this drilling program were successfully grouted.

8.7.4.2 Site cleanup

Efforts were made to restore each drill location to predrilling conditions. The ground was levelled to grade and holes or ruts made by drilling equipment were filled with soil and in some cases resodded. While attempts were made to minimize damage, this was not always possible and compensation was provided in some cases. Photographs were taken of each drill location both before and after the drilling operations and after site cleanup.

CHIPPAWA CREEK ROAD
WELLAND RIVER
GRASSY BROOK ROAD
REG. RD. 63
FRASER
CONRAIL
MACKENNY ROAD
MORRIS ROAD
CROWLAND AVENUE
REG. RD. 84
BIGGER ROAD
CARL ROAD
YOUNG ROAD
MOYER ROAD
MATTHEW ROAD
WISENER ROAD
City of Niagara Falls
City of Thorold
Lot 8 BF
GRASSY BROOK
Lot 8 Con 1
Lot 8 Con 2
Lot 1 BF
Lot 1 Con 1
Lot 1 Con 2
Lot 1 Con 3
WHITE HODGSON
A
A'
B
GL 1 (180)
GL 2 (178)
GL 3 (180)
GL 6 (183)
2921 (178)
2380 (178)
2513 (178)
625 (179)
618 (179)
616 (180)
624 (179)
632 (183)
640 (182)
631 (179)
2434 (178)
SLSA 1220 (181)
SLSA 1221 (181)
SLSA 1222 (181)
SLSA 1223 (182)
SLSA 1224 (182)
SLSA 1225 (182)
SLSA 1226 (182)
531 (182)
4 (276)
5 (276)
200
199
198
197
196
195
1
2
3
4
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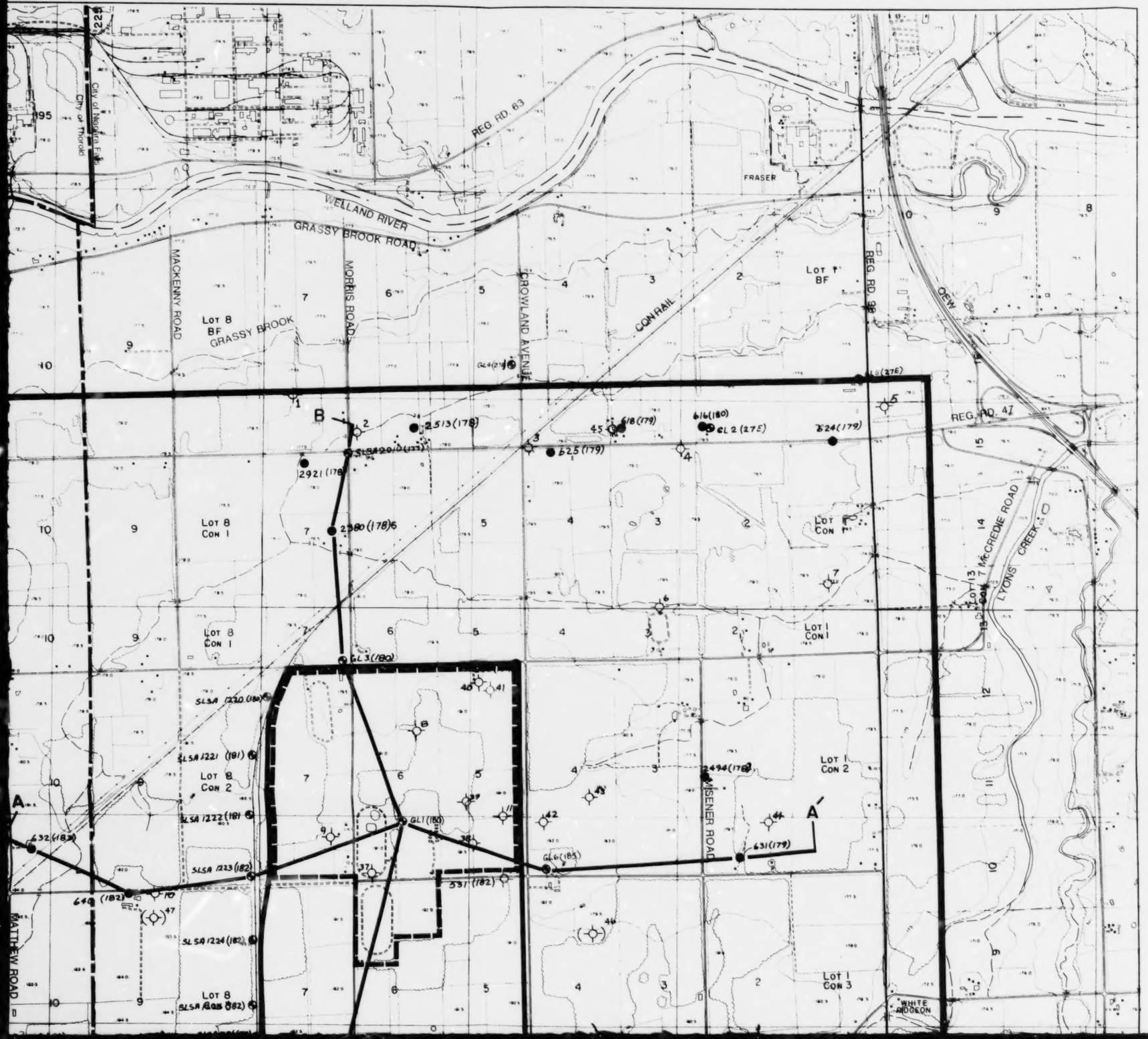


OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

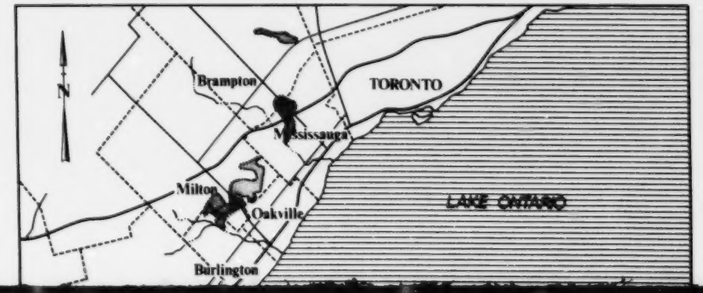
- GL — GARTNER LEE ASSOCIATES LIMITED BOREHOLE
- SLSA — ST. LAWRENCE SEAWAY AUTHORITY BOREHOLE
- 624 / 179 — WATER WELL WITH MINISTRY OF ENVIRONMENT NUMBER / ELEVATION IN METRES ABOVE SEA LEVEL
- GAS AND/OR OIL WELL (TABLE 5, SECTION 8.2)
- GAS AND/OR OIL WELL LOCATION UNCERTAIN, FROM SITE INTERVIEWS (NOTE: WELLS 46 AND 47 SEE NUMBERS 16 AND 7 RESPECTIVELY, TABLE 6, SECTION 8.3)
- A — A' CROSS-SECTION

Proposed Boundary for Partially Integrated Siting Option

Proposed Boundary for Integrated Siting Option (Phase 3B Acquisition Boundary)

Site Vicinity Study Area Boundary

Key Map:



LF-1 East

Lots 5, 6 and 7; Concessions II and III; City of Niagara Falls; formerly in the Township of Crowland

CARL ROAD

YOUNG ROAD

MOYER ROAD

MATHEW ROAD

SCHISLER ROAD

YOKUM ROAD

LINCOLN STREET

COOKS MILLS

LYONS CREEK ROAD

MISENER ROAD

WHITE RIDGEON

MONTROSE ROAD

City of Niagara Falls

City of Welland

CN

LOT 8 CON 1

LOT 8 CON 2

LOT 8 CON 5

LOT 8 CON 6

LOT 1 CON 1

LOT 1 CON 2

LOT 1 CON 3

LOT 1 CON 4

LOT 1 CON 5

A

A'

B

B'

GL3(180)

GL1(180)

GL6(184)

GL5(182)

GL4(180)

SLSA 1220 (180)

SLSA 1221 (181)

SLSA 1222 (181)

SLSA 1223 (182)

SLSA 1224 (182)

SLSA 1225 (182)

SLSA 1226 (183)

SLSA 1227 (183)

SLSA 1228 (181)

SLSA 1199 (182)

SLSA 1200 (184)

SLSA 1201 (178)

SLSA 1202 (178)

SLSA 1218 (182)

SLSA 1219 (183)

MNR 851 (184)

632 (183)

640 (182)

631 (182)

631 (179)

2494 (178)

2522 (182)

646 (182)

741 (181)

2521 (181)

648 (181)

650 (186)

639 (178)

638 (177)

645 (179)

2564 (175)

Contour Interval

1:10000 base mapping pr

Ministry of Natural Resou

Proposed Boundary for Partially Integrated Siting Option

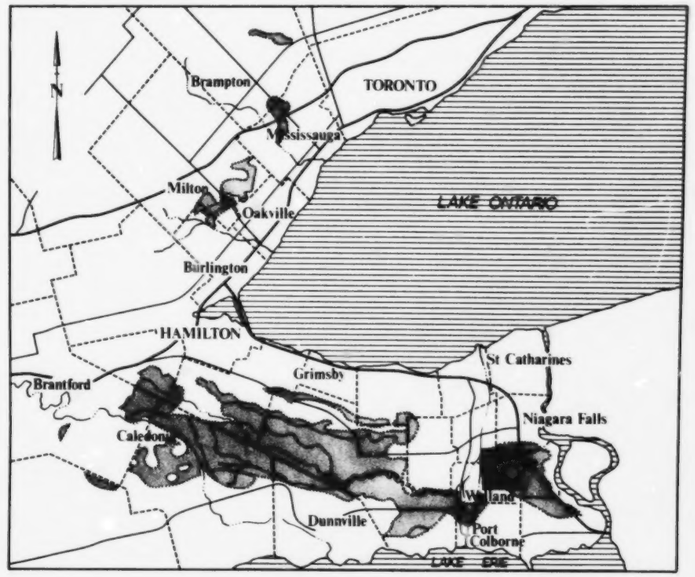
Proposed Boundary for Integrated Siting Option (Phase 3B Acquisition Boundary)

Site Vicinity Study Area Boundary

Key Map:

LF-1 East

Lots 5, 6 and 7; Concessions II and III; City of Niagara Falls; formerly in the Township of Crowland



1000 feet 0 1000

500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Well and Borehole Locations

September 1985

FIGURE 4

Contour Interval in Metres

1:10000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

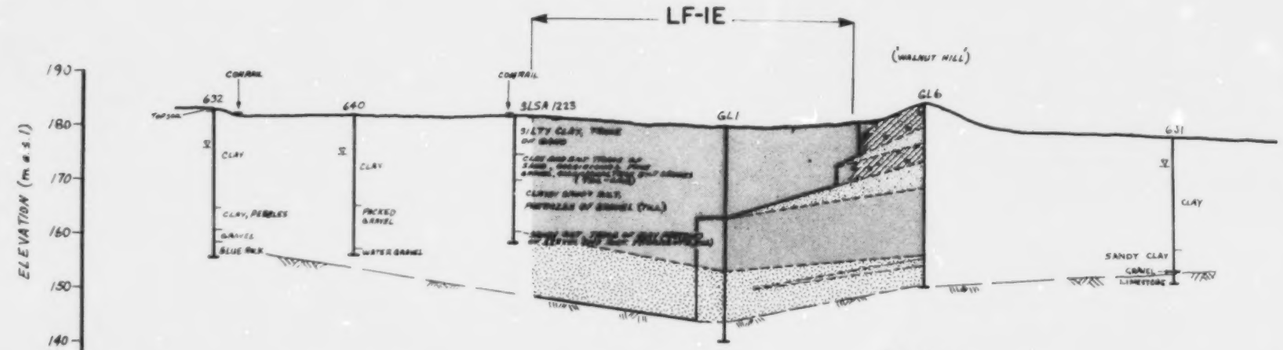
West

A

Looking North

East

A'



SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

(Geologic conditions between boreholes may vary from interpretations shown)

Site LF-1E
CROSS-SECTION A-A'
Figure 5

LEGEND

GL 3 — Gartner Lee Associates Limited (GLAL) Borehole
31F — Ministry of Environment Water Well Record Number
SLSA — St Lawrence Seaway Authority Borehole
SL — Static Water Level in Well at Time of Well Construction
m.a.s.l — Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- CLAYEY SILT AND SILTY CLAY (Upper Glaciolacustrine, Halton Till, and Lower Glaciolacustrine)
- SILT TO SANDY SILT TILL (Local Variant of Halton Till Related to Walnut Hill)
- SAND (Lower Glaciolacustrine)
- SILT TILL (Lower Till)
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

NOTES:
Consult Water Well Record Summary and Borehole Logs in Sections 8.1 and 8.4 for detailed descriptions.
Elevations are approximate
Cross-Section Located in Figure 4

To accompany Phase 4A Technical Appendix
(Geologic Hydrogeologic and Geotechnical Considerations)

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

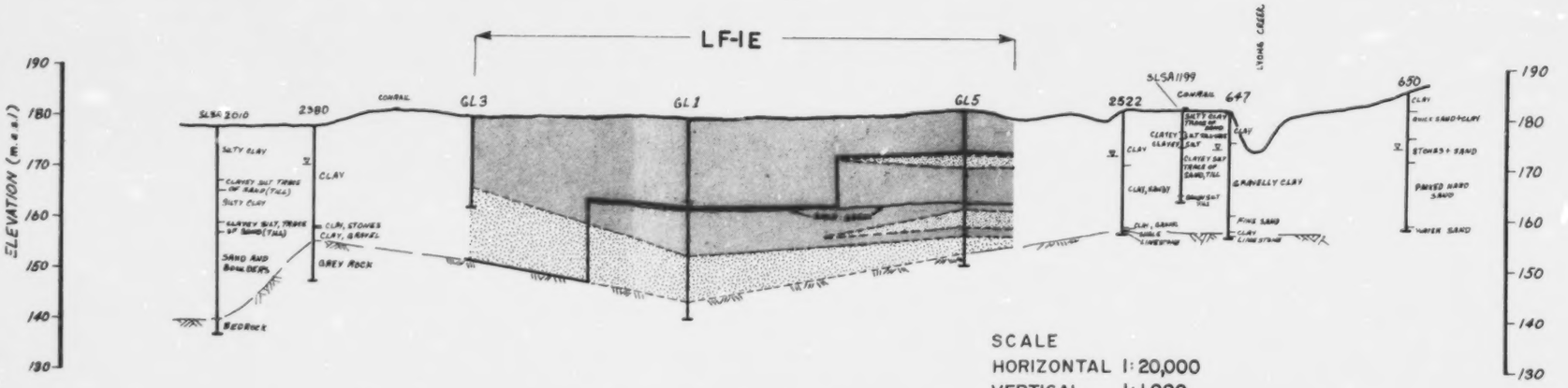
North

B

Looking West

South

B'



SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

(Geologic conditions between boreholes may vary from interpretations shown)

Site LF-1E
CROSS-SECTION B-B'
Figure 6

LEGEND

GL — Gartner Lee Associates Limited (GLAL) Borehole
31F — Ministry of Environment Water Well Record Number
SLSA — St Lawrence Seaway Authority Borehole
SL — Static Water Level in Well at Time of Well Construction
m.a.s.l — Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

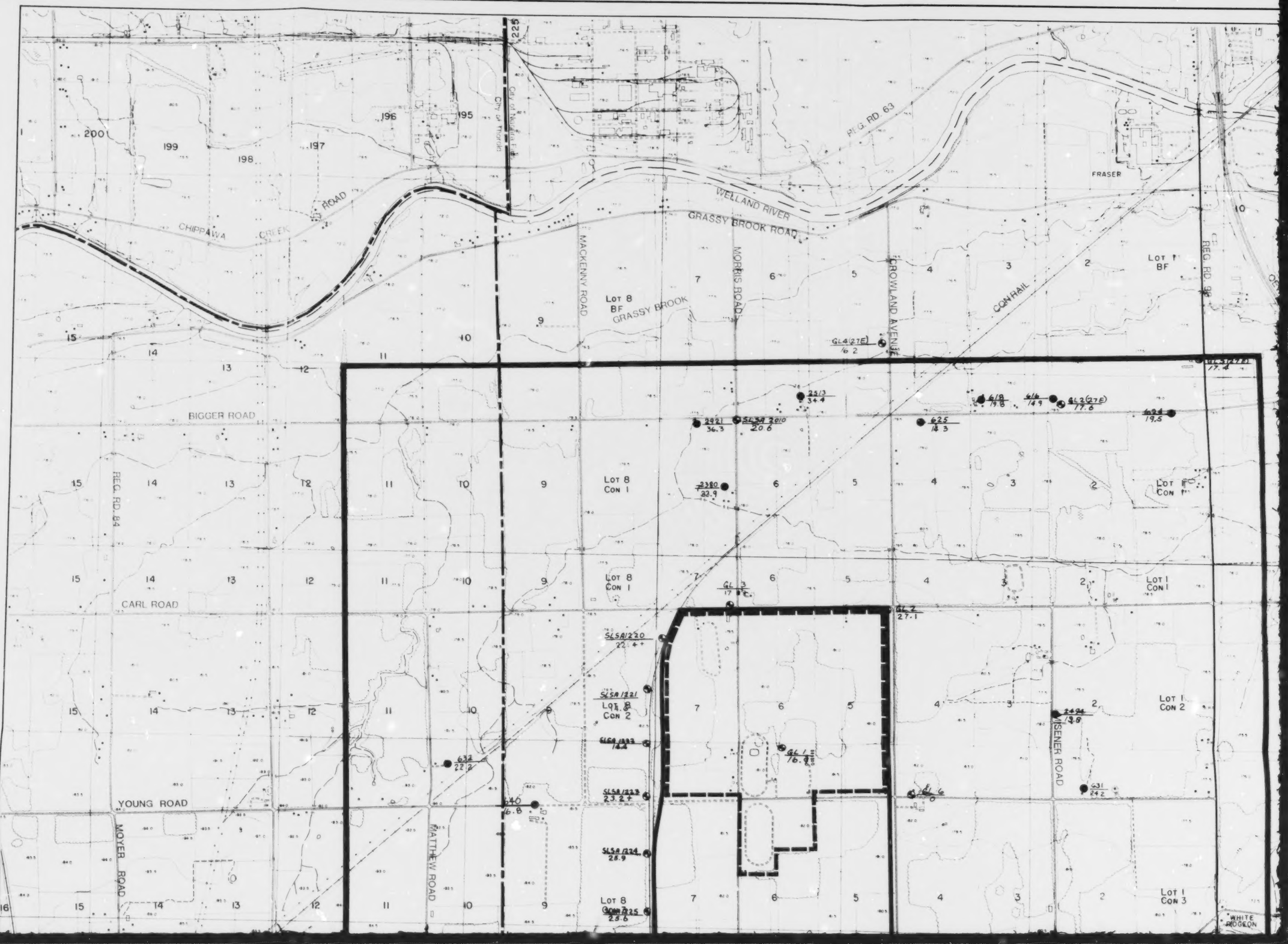
- CLAYEY SILT AND SILTY CLAY (Upper Glaciolacustrine, Halton Till, and Lower Glaciolacustrine)
- SAND
- SILT TILL (Lower Till)
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

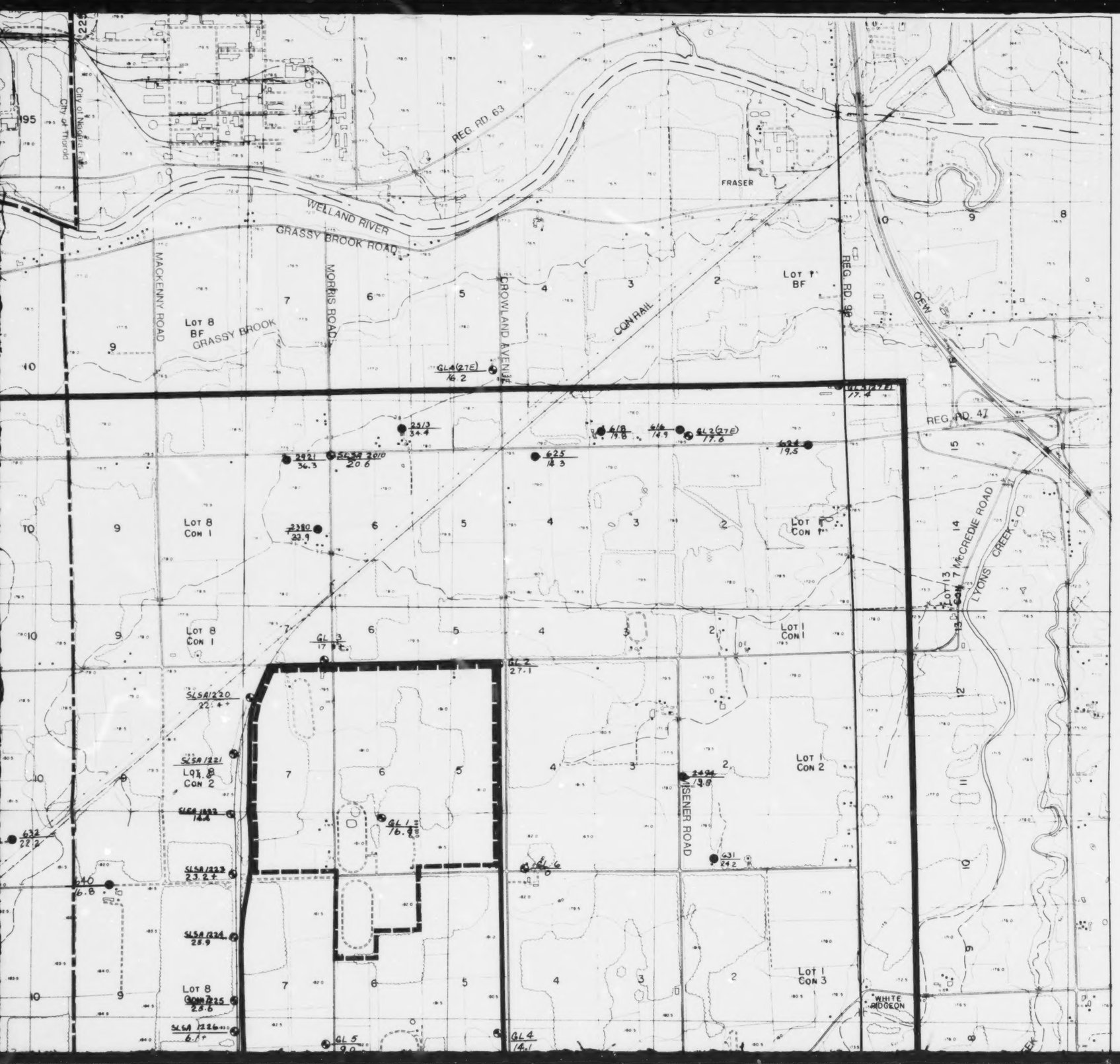
NOTES:
Consult Water Well Record Summary and Borehole Logs in Sections 8.1 and 8.4 for detailed descriptions.
Elevations are approximate
Cross-Section Located in Figure 4

To accompany Phase 4A Technical Appendix
(Geologic Hydrogeologic and Geotechnical Considerations)

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited


CHIPPAWA CREEK ROAD
WELLAND RIVER
GRASSY BROOK ROAD
REG. RD. 63
FRASER
MACKENNY ROAD
MORRIS ROAD
BROWLAND AVENUE
CONRAIL
REG. RD. 98
LOT 8 BF
GRASSY BROOK
LOT 1 BF
BIGGER ROAD
REG. RD. 84
CARL ROAD
YOUNG ROAD
MOYER ROAD
MATTHEW ROAD
VISENER ROAD
LOT 8 CON 1
LOT 8 CON 2
LOT 1 CON 1
LOT 1 CON 2
LOT 1 CON 3
WHITE PIGEON
City of Niagara Falls
City of Thorold
GL4(27E) 16.2
GL4(27E) 17.6
GL3 17.4
GL2 27.1
GL1 16.8
GL6
2321 36.3
SLSA 2010 20.6
2380 22.9
SLSA/220 22.4+
SLSA/221 22.4+
SLSA/223 23.2+
SLSA/224 25.9
SLSA/225 25.6
632 22.2
640 16.8
2313 34.4
625 14.3
6/8 19.8
6/6 14.9
6/4 19.5
2424 13.8
631 24.2



OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

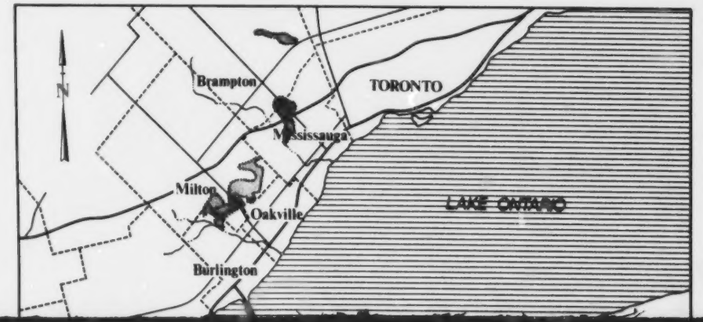
- GL — GARTNER LEE ASSOCIATES LIMITED BOREHOLE
- SLSA — ST. LAWRENCE SEAWAY AUTHORITY BOREHOLE
- 631 — WATER WELL WITH MINISTRY OF ENVIRONMENT NUMBER
- 24.2 — THICKNESS OF CONFINING LAYER IN METRES

- Proposed Boundary for Partially Integrated Siting Option
- Proposed Boundary for Integrated Siting Option (Phase 3B Acquisition Boundary)
- Site Vicinity Study Area Boundary

Key Map:

LF-1 East

Lots 5, 6 and 7; Concessions II and III; City of Niagara Falls; formerly in the Township of Crowland



CARL ROAD
YOUNG ROAD
MOYER ROAD
MATTHEW ROAD
SCHISLER ROAD
CN
COOKS MILLS
LYONS CREEK ROAD
YOKUM ROAD
UNCOLN STREET
City of Niagara Falls
City of Welland
EISENER ROAD
WHITE RIDGEON
MONTROSE ROAD
LOT 8 CON 1
LOT 1 CON 1
LOT 8 CON 2
LOT 1 CON 2
LOT 8 CON 3
LOT 1 CON 3
LOT 8 CON 5
LOT 1 CON 5
LOT 8 CON 6
SLSA/220 22.4+
SLSA/221 LOT 8 CON 2
SLSA/222 14.4
SLSA/223 23.2+
SLSA/224 25.9
SLSA/225 23.6
SLSA/226 6.1+
SLSA/227 23.9+
SLSA/228 22.6+
SLSA 1199 18.3+
SLSA 1200 12.0
SLSA 1201 12.0
SLSA 1202 12.4
SLSA 1218 11.1+
SLSA 1219 15.2+
GL 1 16.9
GL 2 27.1
GL 3
GL 4 14.1
GL 5 9.0
GL 6
632 22.2
640 6.8
638 39.3
639
645 22.6
646 23.5
648 28.2
650 9.1
2494 19.8
2522 23.5
2521 30.5
2564 13.8
631 24.2
Contour Interval
1:10000 base mapping pr
Ministry of Natural Resou

Proposed Boundary for Partially Integrated Siting Option

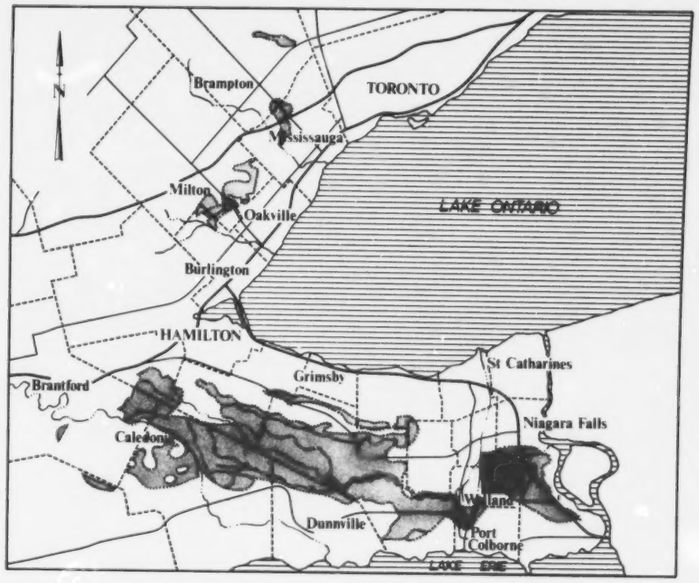
Proposed Boundary for Integrated Siting Option (Phase 3B Acquisition Boundary)

Site Vicinity Study Area Boundary

Key Map:

LF-1 East

Lots 5, 6 and 7; Concessions II and III; City of Niagara Falls; formerly in the Township of Crowland



1000 feet 0 1000

500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Confining Layer Thickness

September 1985

FIGURE 7

Contour Interval in Metres

1:10 000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

CHIPPAWA CREEK ROAD
BIGGER ROAD
CARL ROAD
YOUNG ROAD
MOYER ROAD
REG. RD. 84
MACKENNY ROAD
MORRIS ROAD
MATTHEW ROAD
CROWLAND AVENUE
WISENER ROAD
CONRAIL
REG. RD. 63
REG. RD. 98
WELLAND RIVER
GRASSY BROOK ROAD
GRASSY BROOK
City of Niagara Falls
City of Thorold
FRASER
WHITE MIDGEON
Lot 8 BF
Lot 8 Con 1
Lot 8 Con 2
Lot 8 Con 3
Lot 1 BF
Lot 1 Con 1
Lot 1 Con 2
Lot 1 Con 3

OWMC **Ontario Waste Management Corporation**

Consultant: Gartner Lee Associates Limited

Legend:

- ●, ● DRILLED WELL COMPLETED IN OVERBURDEN, BEDROCK
- ■ DUG OR BORED WELL
- ⬢ UNKNOWN WELL TYPE
- /, × UNUSED, ABANDONED WELL
- ▲ DUGOUT OR POND
- ▼ CISTERN
- \+ ADDITIONAL FIELD INFORMATION

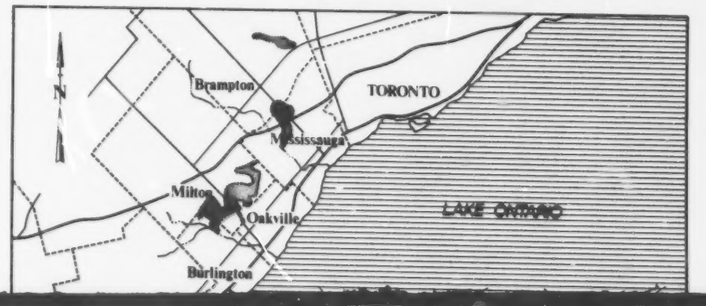
NOTES: Details for wells with Ministry of Environment numbers (3 and 4 digits) are provided in the Summary of Water Well Data (Table 4, Section 8.1); Other numbers accompany wells, cisterns, dugouts or ponds, and locations where 'additional field information' was gathered. Details for these are provided in the Summary of Site Interview Data (Table 6, Section 8.3)

Proposed Boundary for Partially Integrated Siting Option

Proposed Boundary for Integrated Siting Option (Phase 3B Acquisition Boundary)

Site Vicinity Study Area Boundary

Key Map:



LF-1 East

Lots 5, 6 and 7; Concessions II and III; City of Niagara Falls; formerly in the Township of Crowland

CARL ROAD
YOUNG ROAD
MOYER ROAD
MATTHEW ROAD
SCHISLER ROAD
CN
COOKS MILLS
LYONS CREEK ROAD
YOKUM ROAD
LINCOLN STREET
City of Niagara Falls
City of Welland
EISENER ROAD
MONTROSE ROAD
WHITE MODEON
Lot 8 Con 1
Lot 8 Con 2
Lot 8 Con 3
Lot 8 Con 5
Lot 8 Con 6
Lot 1 Con 1
Lot 1 Con 2
Lot 1 Con 3
Lot 1 Con 4
Lot 1 Con 5
Contour Interval
1:10000 base mapping
Ministry of Natural Res

Proposed Boundary for Partially Integrated Siting Option

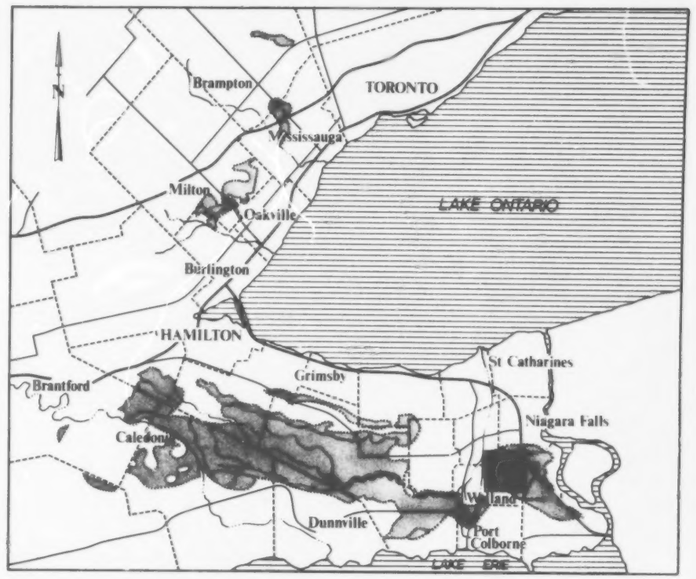
Proposed Boundary for Integrated Siting Option (Phase 3B Acquisition Boundary)

Site Vicinity Study Area Boundary

Key Map:

LF-1 East

Lots 5, 6 and 7; Concessions II and III; City of Niagara Falls; formerly in the Township of Crowland



1000 feet 0 1000

500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Ground Water Use

September 1985

FIGURE 8

Contour Interval in Metres

1:10 000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

Number/
Numéro

4

SITE SELECTION PROCESS - PHASE 4A

TECHNICAL APPENDIX LF-2N

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS

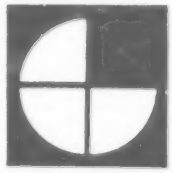
A REPORT PREPARED FOR
THE ONTARIO WASTE MANAGEMENT CORPORATION
BY
GARTNER LEE ASSOCIATES LIMITED

THIS REPORT IS ONE OF EIGHT TECHNICAL APPENDICES DESCRIBING GEOLOGIC, HYDROGEOLOGIC AND GEOTECHNICAL CONSIDERATIONS OF THE CANDIDATE SITES. IT SUPPORTS THE COMPARATIVE EVALUATION STUDY WHICH IS ENTITLED "SITE SELECTION PROCESS; PHASE 4A, SELECTION OF PREFERRED SITE(S), GEOLOGIC, HYDROGEOLOGIC AND GEOTECHNICAL CONSIDERATIONS".

SEPTEMBER, 1985

PROJECT NO: 85-S18.3

Gartner Lee
Associates Limited



Gartner Lee Associates Limited

Consulting Engineering
Geologists
Biologists and
Hydrogeologists

Toronto-Buttonville Airport ▪ Markham, Ontario ▪ L3P 3J9 ▪ 416-477-8400
Telex-06-986278

September 10, 1985.

Dr. B.D. Mitchell,
Director of Corporate Planning
and Development,
Ontario Waste Management Corporation,
2 Bloor Street West,
11th Floor,
Toronto, Ontario,
M4W 3E2.

Attention: Mr. J.G. Micak,
Manager,
Environmental Projects.

Dear Dr. Mitchell:

Re: Site Selection Process - Phase 4A
Technical Appendix LF-2N - Geologic, Hydrogeologic,
and Geotechnical Considerations

Enclosed is our final report on the Geologic, Hydrogeologic, and Geotechnical Considerations at Candidate Site LF-2N. Similar reports prepared for each of the other candidate sites will form the basis for site comparisons.

Thank you for allowing our company to be of service.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

Grant Anderson

E.G. Anderson, P.Eng.,
Project Director.

KJG:jcm
Enclosures.

TABLE OF CONTENTS

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	1.2 OBJECTIVES AND SCOPE	2
	1.3 LOCATION	2
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	2.1 DATA COLLECTION	4
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STUDY TEAM

This report was prepared under the overall direction of Grant Anderson, P.Eng., Project Director and Gunther Funk, Project Manager. Major contributing authors were:

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Geotechnics	Douglas Jagger, P.Eng.
Field Coordination	Norbert Woerns

1.0 INTRODUCTION

1.1 BACKGROUND

The Ontario Waste Management Corporation's (OWMC) site selection process to locate facilities for treating hazardous wastes and disposing the treated waste residues has been a phased process which began in 1981. Initial studies identified 261 hydrogeologic areas throughout southern Ontario which were grouped into six zones. Within the Golden Horseshoe, zone 1 and 2 lands were considered most favourable for facility siting. Twenty candidate areas were identified within the Zone 1 and 2 lands in the Golden Horseshoe in 1983. A total of 152 sites were identified in these twenty candidate areas in 1984 and this number was subsequently reduced in stages to sixteen potential sites and finally to eight candidate sites through the application of various constraints, screening processes, and ranking systems based on multidisciplinary factors. A more complete discussion of the site selection process is provided in the comparative evaluation study (GLAL 1985).

The present stage of study is a comparative assessment of the siting options. This Gartner Lee Associates Limited (GLAL) report documents and interprets available geologic, hydrogeologic, and geotechnical information for Site LF-2N and serves as the data base for input to the comparison study. The candidacy of this site is based on the potential development of a landfill and/or a landfill and physical-chemical treatment facilities. There would be no incinerator at this site. The Phase 3B preliminary assessment of this site was based primarily on existing data

(GLAL 1984b). Phase 4A investigations described in this report add significantly to the geologic, hydrogeologic, and geotechnical data base.

1.2 OBJECTIVES AND SCOPE

The objectives of this study are to provide data for Site LF-2N to accommodate comparison with the other siting options. These objectives have been met through additional investigations. The existing data base has been upgraded where possible and six boreholes have been drilled at selected locations on and adjacent to the site. Each of the boreholes has been continuously sampled to provide detailed geologic logs and soil samples. Boreholes were not instrumented and were grouted on completion.

1.3 LOCATION

Site LF-2N is located within the corporate limits of the City of Mississauga in the Regional Municipality of Peel. It is shown together with the seven other candidate sites in Figure 1 and is presented in greater detail in the figures in the map pocket at the rear of the report.

The site under consideration in this Technical Appendix covers approximately 172 hectares (ha) and includes Lots 9 and 10, Concession 1 E.H.S. in the City of Mississauga. It is bounded on the north by Derry Road (Regional Road 5), on the east by First Line Road, and on the west by Hurontario Street (Highway 10). The site is approximately 7 km southeast of downtown Brampton and about 3 km southwest of Pearson International Airport. The site is roughly bisected by a

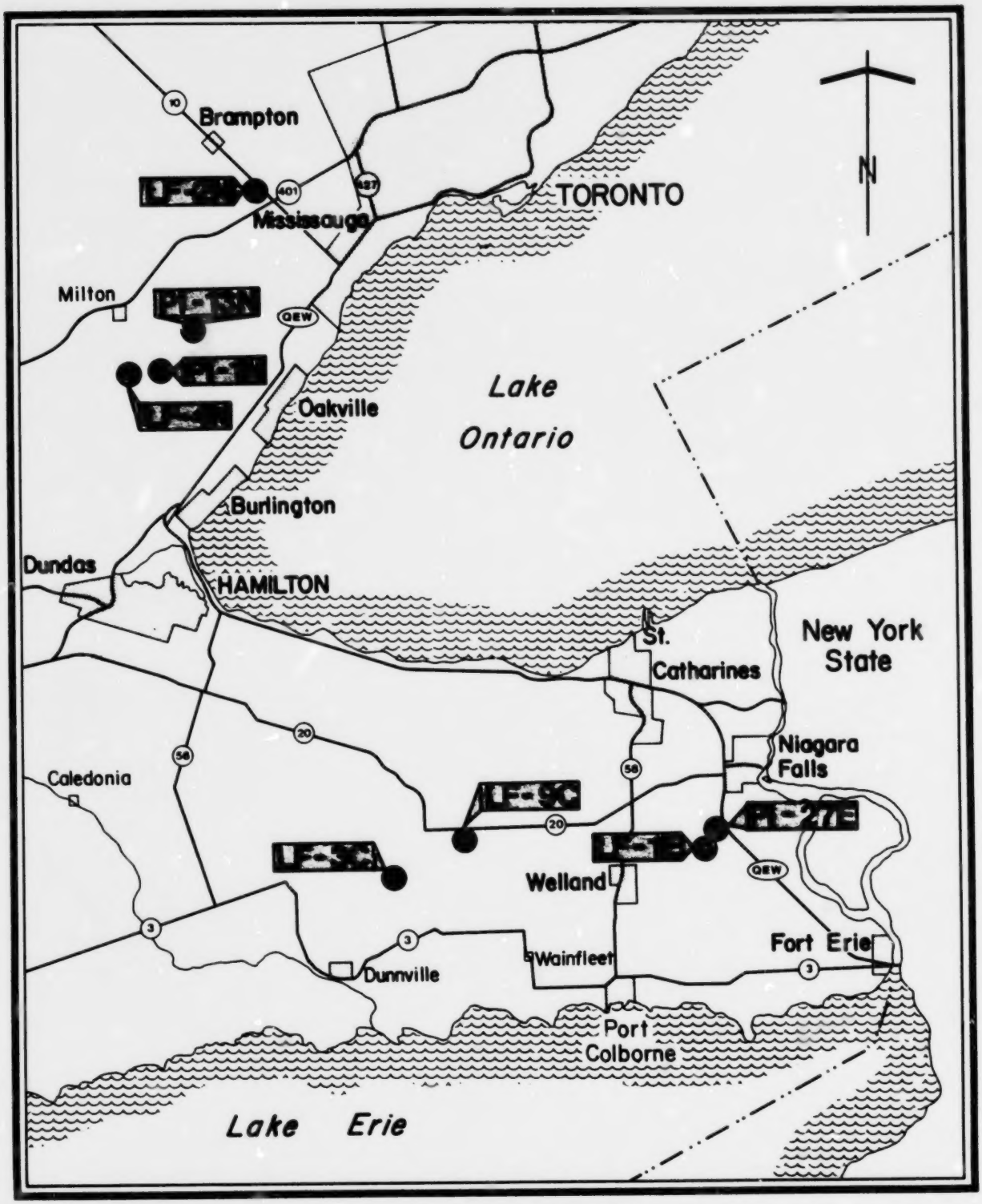


FIGURE 1 LOCATION OF CANDIDATE SITES

hydro corridor which crosses the site from west to east. It contains no perennial streams and is roughly centered in a study area which covers approximately 1600 ha.

2.0 METHODOLOGY

The methodology employed in the collection, compilation, and interpretation of the information base presented in this technical appendix report is described below and is illustrated in Figure 2.

2.1 DATA COLLECTION

The following sources of information were used:

- water well and borehole records; published and unpublished reports, maps and "open file" reports;
- interviews with government agency personnel and local residents; and
- onsite drilling and field survey results.

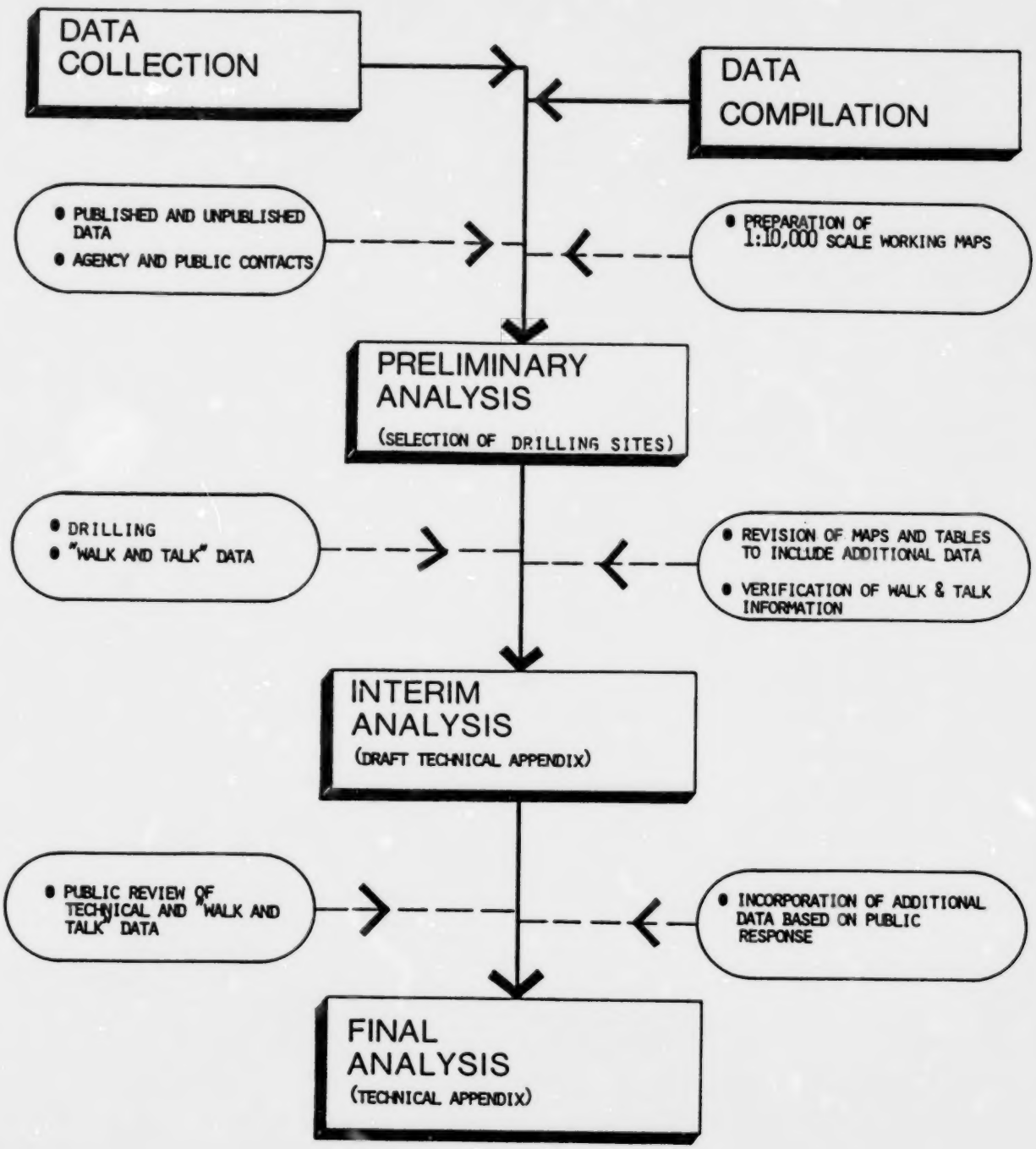
2.1.1 DATA BASE

Numerous reports and maps which contain both regional and local information on the geology and hydrogeology of the candidate sites were assembled during the earlier phases of the site selection process. Reports specific to this site are referenced in the text and are listed in Section 7.0. Data summaries are provided in Section 8.0.

Supplementary information was collected with the co-operation of government and other agencies. This information includes:

Figure 2

Methodology Flow Chart


DATA COLLECTION
DATA COMPILATION
• PUBLISHED AND UNPUBLISHED DATA
• AGENCY AND PUBLIC CONTACTS
• PREPARATION OF 1:10,000 SCALE WORKING MAPS
PRELIMINARY ANALYSIS
(SELECTION OF DRILLING SITES)
• DRILLING
• "WALK AND TALK" DATA
• REVISION OF MAPS AND TABLES TO INCLUDE ADDITIONAL DATA
• VERIFICATION OF WALK & TALK INFORMATION
INTERIM ANALYSIS
(DRAFT TECHNICAL APPENDIX)
• PUBLIC REVIEW OF TECHNICAL AND "WALK AND TALK" DATA
• INCORPORATION OF ADDITIONAL DATA BASED ON PUBLIC RESPONSE
FINAL ANALYSIS
(TECHNICAL APPENDIX)

- copies of original water well records obtained from the Ministry of the Environment, and
- copies of borehole information from the Ministry of Transportation and Communications.

Enquiries with the Ministry of Natural Resources indicated that there are no oil and gas wells on record in the study area. Summaries of these data are presented in Section 8.0. Copies of the data are on file.

2.1.2 INTERVIEWS

Additional information regarding site geology and water use was obtained during interviews with government agency personnel and local residents. The results of interviews are presented in summaries prepared for agency meetings (by GLAL), and on resident interview forms (prepared by Ecologistics Limited). Gartner Lee Associates Limited staff accompanied Golder Associates Limited and a local citizens group representative in a field survey of water use on and adjacent to the site. Meetings were held with the local public interest groups made up of residents and other interested individuals who identified items of geologic and hydrogeologic interest. The summaries of meetings and interview forms are on file. Local water use information summarized from field survey data is tabulated in Table 5 (Section 8.2).

2.1.3 DRILLING AND FIELD SURVEY RESULTS

Borehole locations were selected based on preliminary analysis of available data and input from the public. Six boreholes were completed at selected locations on site to investigate the expected character and continuity of the geologic materials. Drilling and sampling procedures are presented in the document entitled "Phase 4A Drilling and

Sampling Activities and Protocol" (GLAL 1984a) and the detailed methods employed during this study are summarized in Section 8.6.

The drilling program involved the collection of continuous samples from boreholes. These samples were photographed and described in the field, placed in suitable containers, and shipped to the Ontario Geological Survey in Toronto for storage. Split spoon samples were taken at 1.5 m intervals to obtain standard penetration values and samples for moisture content determinations in order to carry out preliminary geotechnical assessments. Detailed borehole logs were prepared based on the field descriptions and on subsequent re-examination of the samples in storage. These logs are presented in Section 8.3 as part of the supporting information package.

2.2 DATA COMPILATION AND ANALYSIS

Data compilation and analysis have proceeded in a staged fashion which is depicted in Figure 2. In the initial work, information such as water well records was compiled in summary tables and illustrated on a series of working maps and cross-sections at a scale of 1:10 000. Maps included plots of:

- data point locations (all sources);
- geology (Ontario Geological Survey reports, constraint mapping results from Phase 3B and Ministry of the Environment maps and reports);
- bedrock elevations (water well and borehole data);
- confining layer thickness (water well and borehole data);

With the completion of the drilling and public survey programs, the working maps were revised to incorporate the additional information that was collected. This technical appendix report presents an interpretation of geologic, hydrogeologic, and geotechnical conditions at LF-2N to date. Draft copies of the data summaries were circulated to the local interest groups as a check for completeness and accuracy.

3.0 REGIONAL GEOLOGY AND HYDROGEOLOGY

The geology and hydrogeology of the Halton-Peel area are summarized and discussed in reports prepared for the Ontario Waste Management Corporation (GLAL 1984b,c). This section is based on these reports and the reader is referred to them for more detail and for a complete list of references on which they are based.

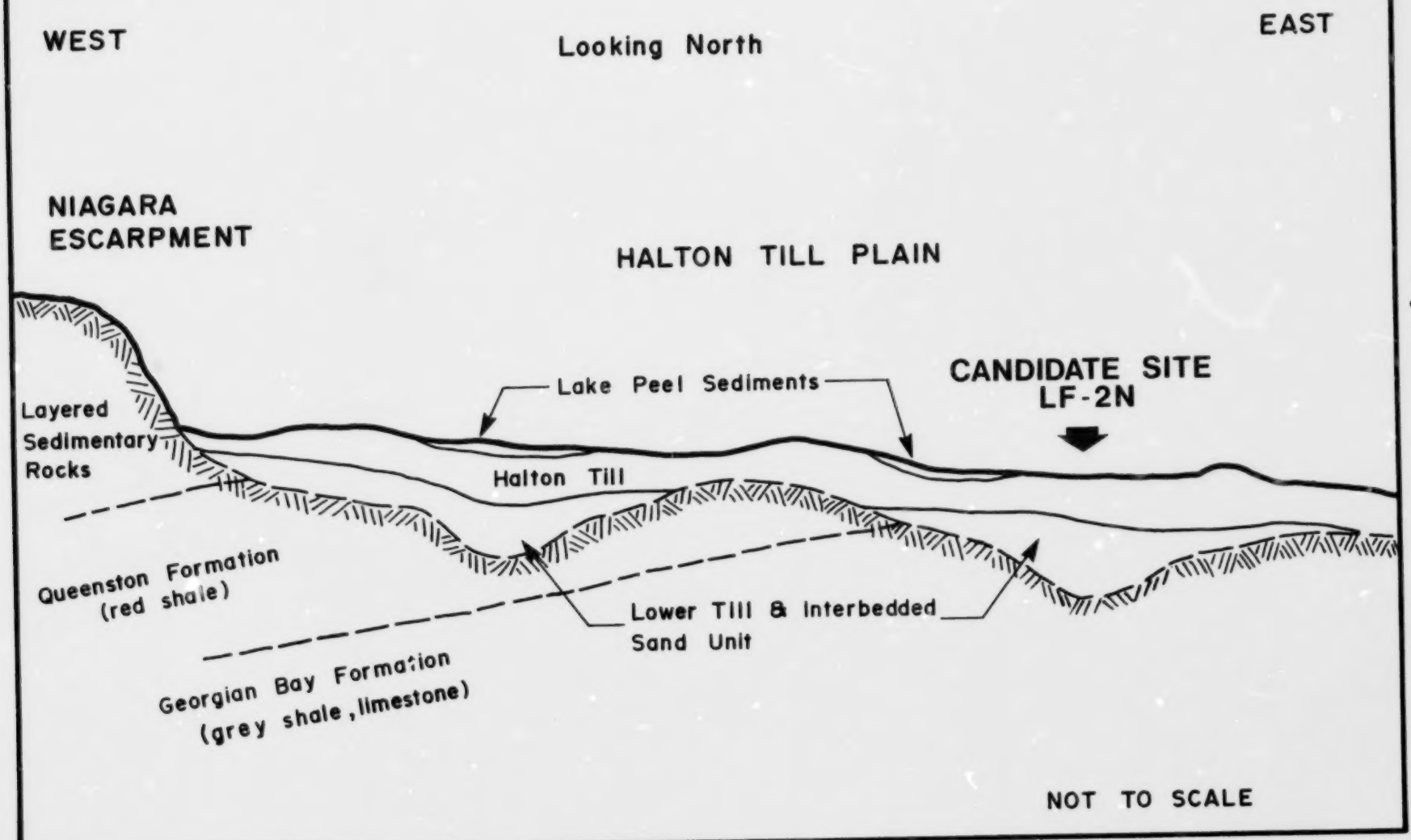
3.1 REGIONAL GEOLOGY

3.1.1 BEDROCK GEOLOGY AND OVERBURDEN THICKNESS

Bedrock in the south-central portion of Ontario consists of a series of sedimentary rock formations which dip gently to the southwest. The various rock formations are consequently exposed on the buried bedrock surface in a series of northwest-southeast trending bands which become progressively younger from northeast to southwest. Figure 3 shows the approximate location of Site LF-2N on a generalized crosssection from the Niagara Escarpment southeastward

FIGURE 3

Cross-Section Sketch Through Halton-Peel Area



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toward Lake Ontario. In the Halton-Peel area, the bedrock is the Georgian Bay Formation (grey shale and limestone) in the east and the Queenston Formation (reddish-brown shale) in the west. The bedrock surface is generally similar to the present land surface and slopes gently from the Niagara Escarpment to Lake Ontario. Bedrock usually occurs within 10 m of the ground surface and creek valleys are commonly eroded into it. Occasional buried valleys and depressions occur on the bedrock surface and, where these are infilled, the drift may be substantially thicker. At several locations water courses have reoccupied portions of bedrock valleys (examples are Sixteen Mile Creek and the Credit River).

3.1.2 QUATERNARY GEOLOGY

Good geologic exposures are infrequent and there has been limited published geologic survey work in the area to date. Available information is summarized and referenced in a previous OWMC report (GLAL 1984c).

Quaternary units are summarized in Figure 3. In view of the lack of detailed geologic studies in the area, only the uppermost till unit (Halton Till) and the Lake Peel glaciolacustrine sediments are referred to by formal names. The underlying deposits are collectively referred to as the 'lower till and interbedded sand unit' on a regional basis although locally it may be practical to define subunits. From oldest to youngest the units are, (1) a group of lower tills and granular deposits which directly overlie the bedrock, (2) the Halton Till, and (3) the Lake Peel glaciolacustrine sediments.

The 'lower till and interbedded sand unit' may contain several tills of varying composition plus interbedded sands, silts, and clays. It is possible that the Wentworth Till is included in this unit (GLAL 1984c). The Halton Till is a clayey silt to silt till and the surficial Lake Peel sediments consist of an intermittent veneer of sands, silts, and clays. The geologic events associated with these deposits began with a series of ice sheet advances and retreats which led to the deposition of the lower tills. Glaciolacustrine and/or glaciofluvial sands, silts, and clays were deposited between glacial advances and were preserved between the till sheets at some locations. The last major ice advance occurred about 12 000 to 13 000 years ago and laid down the Halton Till. The character of this till suggests a fluctuating ice margin, possibly with a glacial lake in front of the ice. Several subunits are known within the Halton Till and are occasionally separated by thin beds of silt, clay, or sand (GLAL 1984c). A series of shallow, short-lived lakes were formed on the Halton Till during the final melting and retreat of the ice. These lakes occasionally left a discontinuous veneer of sand, silt, and clay which is collectively known as the Lake Peel sediments. Since the final glacial retreat, the Halton Till and Lake Peel sediments have been subjected to weathering and erosion to produce the present landscape.

3.2 REGIONAL HYDROGEOLOGY

Figure 3 indicates the geologic and hydrostratigraphic units which have been used in reports and publications for the Halton-Peel area (GLAL 1984b,c). Each of the units is discussed in a regional context beginning with the bedrock and proceeding upward from oldest to youngest.

The upper fractured portions of both the Queenston and Georgian Bay formations are sources of water supply. Regionally, they are considered poor aquifers as yields are generally low (Hickinbotham 1979) and water quality may be marginal to poor. However, where drift aquifers are not present, the bedrock is the only aquifer available. On a regional scale, ground water flow in the upper bedrock is toward Lake Ontario, however local flow patterns may be altered as a consequence of bedrock valleys and depressions.

Potential sand and gravel aquifers in the region are summarized in previous reports (GLAL 1984b). Thin sand and gravel layers, 'sandwiched' between tills or directly above bedrock, occur in the LF-2N study area and local water supplies are developed either in the upper fractured portion of the bedrock or in these granular deposits.

The lower tills vary in texture from stony silty sand to silt and clayey silt. Sand and silt laminae and beds are common and vary in thickness, continuity, and hydraulic conductivity. Large diameter dug or bored wells which appear to be completed in this unit likely obtain water from these granular beds.

The Halton Till is clayey to silty in texture and is a hydrostratigraphic unit of regional extent. Ground water movement through it is very slow because of its fine texture and low hydraulic conductivity. Dug and bored wells occasionally obtain water supplies from the surficial fractured zone, however most supplies are obtained from the bedrock and from granular zones within the 'lower till and interbedded sand unit'. Alluvium may also provide water supplies to shallow dug and bored wells where such wells are completed in flood plains.

4.0 SITE GEOLOGY AND HYDROGEOLOGY

The site-specific geology and hydrogeology of Site LF-2N takes into account the regional data and adds the new borehole information. In addition, data from formal and informal field interviews are integrated into this analysis. Figure 4 (in map pocket) provides locations of the cross-sections and the field data presented in this report.

Results from the GLAL borehole program at this comparative evaluation stage are used to confirm the geology and hydrostratigraphy, and to assess the predictability and uniformity of subsurface conditions. Hydrogeologic discussions are based on the geology and on such additional sources of information as water well and borehole records and water use data provided by local residents. Table 1 compares local geologic and hydrostratigraphic units which are defined for the site and the vicinity. This table provides the framework for the discussions that follow, from the bedrock to the surface.

4.1 SITE GEOLOGY

Six continuously sampled boreholes were drilled on and adjacent to Site LF-2N in 1984 by Gartner Lee Associates Limited. GLAL borehole locations are shown on Figure 4 along with domestic water wells and the Ministry of Transportation and Communications boreholes. Borehole logs and summaries of other subsurface data are included in Section 8.0. Cross-

sections through the study area are presented in Figures 5 and 6 (in map pocket). Geologic names used in the borehole logs (e.g. Halton Till) are used to relate local geology to the established geologic framework. They are based on published descriptions and GLAL borehole logs. No alluvium or Lake Peel sediments were observed on the site.

TABLE 1: SUMMARY OF LOCAL GEOLOGIC AND HYDROSTRATIGRAPHIC UNITS

<table>
<tr><th colspan="2">GEOLOGIC UNITS</th><th colspan="2">HYDROSTRATIGRAPHIC UNITS</th></tr>
<tr><td colspan="2" rowspan="2">HALTON TILL</td><td rowspan="2">CONFINING LAYER</td><td>FRACTURED ZONE (HALTON TILL)</td></tr>
<tr><td>HALTON TILL</td></tr>
<tr><td rowspan="3">LOWER TILL AND INTERBEDDED SAND</td><td>LOWER TILL</td><td rowspan="2">SAND AQUIFER</td><td>LOWER TILL</td></tr>
<tr><td>SAND</td></tr>
<tr><td>LOWER TILL AND SAND</td><td colspan="2">LOWER TILL AND SAND</td></tr>
<tr><td colspan="2">BEDROCK
(GEORGIAN BAY SHALE AND LIMESTONE)</td><td colspan="2">BEDROCK AQUIFER</td></tr>
</table>

4.1.1 TERRAIN

Site LF-2N is located on a gently rolling portion of the Halton Till Plain. A northeast-southwest trending moraine-like ridge occurs along the southwest edge of the site (GLAL 1984b) and a northwest-southeast trending drainage

divide crosses the site. There are no permanent streams or waterways on the site and shallow swales and ditches provide drainage. About three-quarters of the site drains northeast to tributaries of Etobicoke Creek. The remaining area drains southwest to Fletchers Creek. Elevations (above sea level) range from about 203 m in the west to about 190 m in the east.

4.1.2 BEDROCK GEOLOGY AND DRIFT THICKNESS

Dark grey, thinly bedded shale with thin carbonate interbeds was encountered and cored in all six GLAL boreholes. Although previous regional mapping (Telford et al. 1976) placed the site within an area underlain by the Queenston Formation, the bedrock encountered in the GLAL boreholes is similar to the descriptions for the Georgian Bay Formation. Occurrences of "blue shale" in water wells on the site and at locations immediately adjacent to the site have also been interpreted as the Georgian Bay Formation, and it is reasoned that the site is probably underlain by this unit. "Red shale" is reported in slightly more than half of the local water well logs, particularly in the southern third of the study area, and the contact with the Queenston Formation is probably close to the site.

The site is located over a bedrock depression which may be connected to the bedrock valley occupied by the Credit River to the southwest (GLAL 1984c). Bedrock elevations on site range from approximately 160 to 180 m.

Overburden thicknesses on the site are in the range of 20 to 34 m. The thinner overburden corresponds to the areas of higher bedrock elevation (the area in the vicinity

of Borehole GL6 is an example) and the thicker overburden to the areas of lower bedrock elevation (the area in the vicinity of Borehole GL1 is an example). Bedrock outcrops were noted in Fletchers Creek near First Line West by Telford et al. (1976) and bedrock is known to occur at or near surface along Highway 401, south of the study site.

4.1.3 LOWER TILL AND INTERBEDDED SAND UNIT:

Up to three tills were recognized below the Halton Till during logging of the GLAL boreholes. These tills and the interbedded sands with which they occur are collectively referred to here as the 'lower till and interbedded sand unit'. This unit ranges in thickness from 13.6 m in Borehole GL2 to 27.3 m in Borehole GL1. The tills are typically sandy silts which demonstrate textural variability. Sand interbeds range from laminae to beds several metres in thickness. Sand layers between 1 and 5.6 m thick occur in Boreholes GL3, GL4, GL5, and GL6 and portions of the till contain interbeds of sand in all of the boreholes.

Reviews of the cross-sections in Figures 5 and 6 and the borehole logs in Section 8.3 indicate that several of the sand layers and/or sandy sections of till exist at similar elevations and it is considered likely that some of these are continuous beneath the site and beyond the site boundaries. Both figures (5 and 6) indicate a continuous sand layer at the base of the confining layer.

4.1.4 HALTON TILL

The Halton Till was encountered at surface in all six GLAL boreholes (Section 8.3). It has a generally silty texture, is clayey silt at Borehole GL1, and contains occasional fine

sand laminae. The Halton Till is finer textured and more uniform than the underlying lower tills. Due to the silty nature of both the Halton Till and some segments of the lower till, the contact between the two tills is not always distinct and boundaries are tentative. In Boreholes GL2 and GL3, 0.9 to 1.5 m of laminated silty clays, clayey silts, and silts are present between the Halton Till and the lower tills. Somewhat thinner fine sand occurrences were noted between the tills in Boreholes GL5 and GL6. Thicknesses of the Halton Till encountered in GLAL boreholes vary from about 5 to 11 m.

A subtle colour change occurs in the Halton Till from brown to grey brown or grey between depths of about 3.5 and 4.5 m in GLAL boreholes. Similar colour changes are noted between 2 and 4 m in nearby MTC boreholes (Section 8.3). Based on GLAL boreholes, the upper 1 to 3 m of the Halton Till is heavily fractured and fracturing is common to about 4 m. Fracture frequency decreases rapidly with depth and fractures are infrequent below about 5 m. The deepest evidence of fracturing in the Halton Till was noted in Borehole GL6 at a depth of 6.1 m (Section 8.3).

4.1.5 DISCUSSION

The Halton Till is continuous beneath the site but the fractured zone probably extends through this unit at some locations. It is a relatively uniform and predictable silt-clay unit containing occasional thin and discontinuous sand lenses. The underlying lower till and interbedded sand unit is texturally and stratigraphically variable. Apparently continuous granular zones occur within this unit and there are numerous till-sand interbeds present.

4.2 SITE HYDROGEOLOGY

The Phase 4A field work incorporates first-hand geologic descriptions and interpretations with the existing data base (primarily water well record and borehole information). Hydrogeologic analyses utilize the geology, the water well and borehole records, information obtained from the public, information from researchers in similar hydrogeologic settings, and the experience of Gartner Lee Associates Limited staff.

Descriptions of the hydrostratigraphic units, flow systems, ground water use, and potential contaminant pathways are presented in the following sections.

4.2.1 HYDROSTRATIGRAPHY

Four major hydrostratigraphic units occur at Site LF-2N. They are indicated in Table 1 together with the geologic units and from bottom to top they are:

1) the bedrock aquifer,
2) the lower till and sand,
3) the sand aquifer, and
4) the confining layer.

Aquifers at the site include the bedrock, granular zones within the lower till and sand unit, and the sand unit. The confining layer is comprised of fine-textured deposits which have low hydraulic conductivities and which are considered to be relatively uniform in thickness and texture. The confining layer comprises the Halton Till and that portion of the 'lower till and sand unit' which occurs above the sand aquifer.

4.2.1.1 Bedrock aquifer

The bedrock is a source of water to slightly more than half the wells in the study area. Bedrock consists of interbedded shale and carbonate rock. Fractures are considered to be the source of water to bedrock wells.

Pumping rates from drilled bedrock wells range from 0.08 to 0.8 litres per second (L/s). Drawdowns are generally large and about a third of the wells report test pumping rates less than 0.1 L/s. Depths of penetration into the bedrock vary from less than a metre to a maximum of 58 m, however three quarters of the wells report adequate supplies within about 13 m of the bedrock surface.

The hydraulic conductivity of the upper portion of the bedrock on and adjacent to Site LF-2N is estimated to be 2×10^{-6} m/s. This is the approximate geometric mean of several determinations using test pumping data in the water well records and procedures described by Walton (1962) and Ogden (1965).

4.2.1.2 Lower till and sand

Silty sand to sandy silt till and interbedded sands occur between the bedrock and the sand aquifer. The sands are a source of water where shallower granular deposits are absent or incapable of supplying requirements. A hydraulic conductivity of 1×10^{-7} m/s is assigned to this unit to account for the generally sandy texture of the till and the occasional sand interbeds. The sand interbeds themselves are assigned a hydraulic conductivity of 1×10^{-6} m/s to reflect their generally silty texture. The lower till and sand unit contains a predominantly sandy zone which appears present beneath most of the site.

4.2.1.3 Sand aquifer

Within the study area about half of the wells obtain water from sand and/or gravel aquifers. More than three quarters of these wells utilize the sand beds which occur in the upper portion of the 'lower till and interbedded sand' geologic unit between 180 and 190 m elevation. This sand interval appears to correlate with the sand interval identified in the GLAL boreholes and illustrated in the cross-sections (Figures 5 and 6). The average hydraulic conductivity of the sand is estimated to be 1×10^{-6} m/s based on textural descriptions of the unit. Pumping rates from drilled wells in the sand are not substantially different from bedrock wells.

4.2.1.4 Confining layer

The confining layer at Site LF-2N includes the Halton Till and the upper portion of the underlying, lower till. The thicknesses of each of these subunits in the GLAL boreholes are noted in Table 2 along with selected hydrogeologic parameters. The confining layer terminates at sand deposits which appear to be continuous between some boreholes. The confining layer ranges in thickness between 8.3 and 17.6 m in the GLAL boreholes.

The 'lower till' portion of the confining layer has textures which vary from silt to silty sand. It is assigned an average hydraulic conductivity value of 1×10^{-8} m/s which is an order of magnitude less than that of the unfractured Halton Till. This value lies within the ranges indicated for these textures by Freeze and Cherry (1979).

The thickness of the 'lower till' within the confining layer ranges from 1.6 m in Borehole GL1 in the northern part of the site to 7.1 m in Borehole GL3 in the eastern part of

TABLE 2: SUMMARY OF CONFINING LAYER CHARACTERISTICS

BOREHOLE / PARAMETER	THICKNESS OF CONFINING LAYER SUBUNITS			THICKNESS OF CONFINING LAYER
	HALTON TILL		LOWER TILL	
	FRACTURED (m)	UNFRACTURED (m)	(m)	(m)
GL1	5.0	1.7	1.6	8.3
GL2	5.0	5.7	4.8	15.5
GL3	5.0	0.9	7.1	13.0
GL4	5.0	0.1	3.7	8.8
GL5	5.0	6.0	6.6	17.6
GL6	5.0	2.2	6.4	13.6
Average Hydraulic Conductivity (m/s)	$1x10^{-7}$	$1x10^{-9}$	$1x10^{-8}$	
Average Porosity	0.0001	0.3	0.3	

Notes - Unfractured porosity values are estimates of total intergranular porosity

- The fractured porosity value is the effective fracture porosity reported by Desaulniers (1982)

- Porosity values in the unfractured materials reflect intergranular porosity. Additional fracture porosity is present in the fractured zone. These fractures are accompanied by increased hydraulic conductivities with the result that ground water can potentially move more rapidly along fractures.

the site. This variability is a result of the different depths at which sand layers are encountered. Portions of the lower till also display increased textural variability in Boreholes GL5 and GL6 by the more frequent occurrence of sandy beds up to 10 cm thick. There is a possibility that more sand beds could exist in the lower till than were encountered during the drilling program with the result that the confining layer could be further reduced in thickness.

Both the unfractured and fractured subunits of the Halton Till are included in the confining layer (Table 1). The Halton Till ranges in texture from sandy silt to clayey silt and is assigned an average hydraulic conductivity of 1×10^{-9} m/s. This value is applied here because textural conditions are similar at this site and Site LF-4N. Previous work at Site LF-4N (GLAL 1980) indicated a maximum hydraulic conductivity of 1×10^{-9} m/s based on in situ slug tests and a value of 5×10^{-10} m/s based on a laboratory test using a triaxial apparatus.

The upper portion of the confining layer at Site LF-2N is heavily fractured to depths up to 3 m and fractures are common to depths of about 4 m according to GLAL borehole logs (Section 8.3). Fracture frequency declines rapidly with depth and fractures become more tightly closed. Based on the borehole logs, it is estimated that fracturing is generally limited to depths of about 5 m and while a few fractures are noted at greater depths, they are rare. The deepest fracture noted in the Halton Till occurs at 6.1 m in Borehole GL6.

Freeze and Cherry (1979) note that deposits of clayey or silty till and glaciolacustrine deposits in southern

Ontario contain networks of hairline fractures which are essentially vertical and which are responsible for hydraulic conductivities one to three orders of magnitude greater than in unfractured materials. Based on this information, fracturing is considered to be responsible for an hydraulic conductivity difference of about two orders of magnitude between the fractured zone and the unfractured zone. A hydraulic conductivity of 1×10^{-7} m/s is therefore applied to the fractured zone. An effective fracture porosity of 0.0001 is assigned to the fractured zone based on Desaulniers' (1982) data. Confining layer thicknesses are provided in Figure 7 (in map pocket).

4.2.1.5 Discussion

The confining layer consists of lower till and unfractured and fractured Halton Till subunits. It varies in thickness between 8.3 and 17.6 m in the GLAL boreholes. The lower till portion varies in thickness and texture and could potentially be excluded from the confining layer at some locations if sandy textures were dominant. The unfractured Halton Till is less than a metre thick in two GLAL boreholes and could be absent at some locations in view of its variability in thickness. Under a combination of the above conditions, it is possible that the only confining material present would be the fractured Halton Till.

4.2.2 GROUND WATER FLOW REGIME

Infiltration is the source of ground water and differences in hydraulic head provide the driving force for ground water flow systems. At Site LF-2N, a shallow lateral flow system is considered to exist in the saturated portion of the fractured zone (fractured Halton Till). A vertical flow

system transports ground water down and through the confining layer and deeper systems operate in the lower till and sand unit and the bedrock. Ground water flow is essentially vertical in fine-textured materials and primarily lateral in granular deposits which have lateral continuity and lateral gradients. Ground water flow in the bedrock is considered to be mainly lateral.

The water table occurs in the fractured zone and its shape is usually a reflection of surface topography. Fractures and ground water flow diminish rapidly to the base of the fractured zone which extends to a depth of about 5 m on the site. The shallow flow system is most active in the near-surface saturated zone where fracturing is most common and where fracture permeability is best developed.

Movement in the shallow flow system is essentially lateral and rates and directions of flow are dependent on elevation differences in the water table. Local discharges probably occur on a seasonal basis to intermittent water courses in the north-east portion of the site. Topography slopes generally eastward on the site at a gradient of about 0.015. Applying a hydraulic conductivity of 1×10^{-7} m/s, an effective fracture porosity of 0.0001, and an average and average lateral water table gradient of 0.015 to Darcy's Law yields an average linear ground water velocity of about 500 m per year. Estimates of fracture flow rates are usually large relative to intergranular flow rates because of large differences between intergranular and fracture porosity. Fracture flow rates are unrealistically large if the rates are interpreted as 'straightline' flow pathways because fracture interconnec-tions are generally complex and poorly developed.

Table 3 presents a summary of average vertical ground water flow rates and hydrogeologic conditions for the confining layer. An average downward hydraulic gradient of 0.2 was estimated by comparing the reported static water levels in onsite and adjacent water wells with a water table assumed to be at ground level. The flow rates in Table 3 are calculated using methods described by Freeze and Cherry (1979) which is reproduced in Section 8.4 along with a sample calculation. A more accurate assessment of ground water flow rates through the confining layer using advection and diffusion calcualtions is contained in Appendix A of the report entitled "Site Selection Process; Phase 4A, Selection of Preferred Site(s), Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

The hydrogeologic significance of granular deposits is dependent on their extent and continuity. If they are small and encapsulated as lenses in the till, they will not significantly affect rates or directions of ground water flow.

The sand aquifer which underlies the confining layer is considered continuous and could provide a pathway for offsite ground water movement.

TABLE 3: ESTIMATED RATES OF VERTICAL FLOW IN THE CONFINING LAYER

BOREHOLE	FRACTURED CONFINING LAYER - HALTON TILL (m/s)	UNFRACTURED CONFINING LAYER - HALTON TILL AND LOWER TILL (m/s)
GL1	9×10^{-6}	3×10^{-9}
GL2	5×10^{-6}	2×10^{-9}
GL3	2×10^{-5}	5×10^{-9}
GL4	3×10^{-5}	1×10^{-8}
GL5	9×10^{-6}	3×10^{-9}
GL6	9×10^{-6}	3×10^{-9}

Notes:
- Multiply by 3.15×10^{7} for flow rates in metres per year.
- Thicknesses and selected hydrogeologic parameters for the confining layer sub-units are provided in Table 2.

Ground water movement in the bedrock aquifer beneath the site is probably lateral along fractures and bedding planes. There is insufficient water level information to clearly infer a direction of flow, however flow rates in the bedrock aquifer are estimated to be about 300 m/yr. This is based on an average hydraulic conductivity of 2×10^{-6} m/s, a porosity of 0.001 and an average gradient of 0.005 (from reported static water levels in wells, Table 4, Section 8.1). As indicated previously, fracture flow rates may be unrealistically large if they are interpreted over 'straight-line' distances since fracture connections are usually complex and may be indirect or poorly developed.

4.2.3 GROUND WATER USE

Water use information is based on water well record data and on information collected from residents and landowners on the site and on directly adjacent properties.

4.2.3.1 Availability

Water supplies for domestic, stock, and general agricultural purposes are obtained primarily from wells. Bored/dug and drilled wells are all common. Water use information is summarized according to source in Figure 8 (in map pocket) and is summarized in Table 5 (Section 8.2).

Based on water well records and field information surveys, slightly more than half the wells in the study area obtain water from sand aquifers in the overburden. (Slightly less than half the wells obtain their supplies from bedrock). Approximately 20 wells (in addition to those for which MOE well records are available) were identified on the site and on adjacent properties during field surveys.

Reported pumping rates from the bedrock and the granular deposits appear not to differ substantially and both are considered poor to moderate aquifers. Hickinbotham (1979) has mapped most of the area as yielding less than 0.2 L/s from both bedrock and overburden sources. Within the study area, about half the drilled wells were test pumped at rates between 0.2 and 0.8 L/s while the remainder were tested at rates less than 0.2 L/s. About half the bedrock wells obtained adequate supplies after penetrating 7 m or less of bedrock. Most overburden wells are dug or bored and provide storage for peak use.

4.2.3.2 Quality

Water quality in the granular aquifers is reported as 'fresh' on the water well records. Quality in the bedrock is also reported as 'fresh' in all but a few instances where deeper wells yield 'salty' water. Drinking water is brought in at one residence where ground water is reportedly 'very hard'.

4.2.4 POTENTIAL CONTAMINANT PATHWAYS

In general, there are two pathways by which contaminants could potentially leave this site; these are (1) natural pathways along ground water flow systems and (2) man-made pathways along such structures as abandoned and unplugged wells and tile drains. Natural pathways are discussed in the sections on Site Hydrogeology (4.2.1) and Ground Water Flow Regime (4.2.2).

Efforts have been taken to identify and locate man-made structures such as water wells, tile drainage systems and excavations which may be located on the site. These structures

could act as conduits along which contaminants could potentially move. For example, improperly sealed or abandoned wells which penetrate the confining layer could provide access to underlying aquifers. Shallow structures such as granular trench backfill and drainage tiles could provide an off site pathway to surface water and shallow ground water.

Fourteen water wells are known on the site (Figure 8). Eight were identified through the field interviews and six were previously known from Ministry of the Environment well records. All but three dug/bored wells are in active use. All the wells probably penetrate the confining layer. No oil and gas wells are known on the property or in the study area and present information indicates that none of the site is tile drained.

Excavations are believed to be limited to the immediate vicinity of buildings on the site and to footings for the onsite hydro towers. No extensive corridors of permeable backfill materials were identified from the "Walk and Talk" interview information.

5.0 GEOTECHNICAL CONSIDERATIONS

This section provides a preliminary assessment of Site LF-2N from a soils engineering viewpoint. The geologic setting is described in detail in Section 4.0 of this report.

The geologic data base has been supplemented by standard penetration split spoon tests taken at approximately 1.5 m intervals in each of the six GLAL boreholes. The standard penetration (N) values have been used as a guide in estimating the relative density and consistency of the various geologic units. Shear strengths noted here are estimated from correlating the N values with empirical shear strength relationships. Moisture contents are presented along with N values on the geologic logs in Section 8.3.

Geotechnically, there are three major zones within the overburden. From the surface downward they are: (1) a dense to very dense desiccated layer of Halton Till, (2) an underlying thin stratum consisting of the lower Halton and upper portion of the lower till and (3) a series of very dense deposits of granular and till materials which extend to bedrock.

The desiccated crust varies in thickness from about 4 to 9 m and N values are generally greater than 30 (blows per 0.3 m). Where clay textures are absent, the crust will behave as a dense to very dense cohesionless material. Where clay textures are present, it will behave as a very stiff to hard cohesive material with undrained shear strenths in excess of 200 kPa. The in situ moisture content ranged from 8 to 14%. Locally, the upper 1 to 2 m is less dense.

The weaker stratum beneath the desiccated crust is part of the Halton Till except in Boreholes GL3 and GL6 where it extends into the lower till. This stratum is relatively thin with approximate thicknesses of 1 to 3 m. The N values normally range from about 19 to 29 and correspond to an

undrained shear strength of 125 to 200 kPa. In general, soil moisture contents vary from 8 to 12% with occasional values to 21% within the more cohesive zones.

The 'sand' and 'lower till and sand' subunits are very dense with N values greater than 50 although some intervals were noted to be less dense. In situ moisture contents are typically in the 5 to 10% range. Very dense saturated sand seams with moisture contents usually between 10 and 20% occur within the till.

Preliminary assessments based on GLAL borehole data indicate that geotechnical conditions are generally adequate for site development from a soils engineering point of view. However, proper design should be carried out within the framework of the geotechnical guidelines provided below. As well, all geotechnical aspects will require further investigation during the Phase 4B work on the preferred site.

Temporary excavations can safely be carried out to depths of about 15 m within the till at side slopes of 1:1 or less. Preliminary calculations indicate that excavations should not terminate within 2 to 4 m of buried sand seams to safeguard against heave. Where excavations intersect saturated sand layers, ground water control will be necessary.

Treated waste residues cold be placed to thicknesses of about 1.5 times the depth of the cells (based on a waste density of 1.35 tonnes per cubic metre) without creating a surcharge load. Provided there is no surcharge load within the cell base, settlement will be minimal. Where such

fills could overlie the weaker stratum (as at Boreholes GL1, GL2, GL4, and GL5) settlement aspects should be investigated in detail. For the above-ground option, fills could be constructed to 15 m above ground surface at 3:1 side slopes.

The allowable bearing pressure is generally adequate for light and medium weight structures with shallow strip or conventional pad footings. As a guide, an allowable bearing pressure of 300 kPa can be adopted for footings founded in the upper 2 m of the Halton Till. For footings founded in the weaker stratum below the desiccated crust, the allowable bearing pressure is lower, possibly about 200 kPa. Settlement of structures with properly designed footings should not exceed tolerable limits.

For heavy structures, it will likely be necessary to transfer loads to the very dense zones of the 'lower till and sand unit' where the allowable bearing pressure is generally adequate.

In general, subsoils on this site have good handling and workability characteristics. Wet-weather handling may require special measures and procedures due mainly to the clay content. Trafficability is also generally good except during wet weather.

6.0 SUMMARY

Site LF-2N is located on the Halton Till Plain within the corporate limits of the City of Mississauga. The site is

underlain by interbedded shales and carbonates of the Georgian Bay Formation. Overburden on the site ranges between 20 and 34 m in thickness and consists of a series of lower tills and interbedded sand deposits overlain by the Halton Till.

Hydrogeologic units include (1) the bedrock aquifer, (2) the lower till and sand, (3) the sand aquifer, and (4) the confining layer. The confining layer extends from the surface to the sand aquifer and includes a lower till subunit and fractured and unfractured zones of the Halton Till. The fractured zone is approximately 5 m thick. Ground water movement in the fractured zone is primarily lateral in directions which generally follow topographic gradients. Hydraulic gradients across the confining layer are downward and ground water flow across the confining layer is generally vertical. Flow rates through the unfractured portion of the confining layer are about 0.1 m per year. The confining layer is thin, locally variable and may be weathered through its entire thickness at some locations.

The upper bedrock and granular deposits within the 'lower till and interbedded sand unit' are the major sources of water to wells. Water quality is usually reported to be 'fresh' although deeper bedrock supplies may be 'salty'.

Geotechnically, the tills are typically very stiff to hard with a thin, weaker stratum below the desiccated crust at some locations. Temporary excavations can be safely taken to 15 m at 1:1 side slopes or less. However, due to the potential for heave, excavations should not be terminated within 2 to 4 m of saturated sand seams. Where such seams are

intersected, ground water control will be necessary. Treated waste residues may be placed to thicknesses of about 1.5 times cell depth below grade. For the above ground option, fills could be placed at 3:1 slopes to heights of 15 m above ground surface. Adequate bearing pressure is generally available for building foundations. For heavy structures loads should be transferred to the very dense lower till and sand unit.

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8.0 SUPPORTING INFORMATION

8.1 SUMMARY OF WATER WELL DATA (TABLE 4)

8.2 SUMMARY OF SITE INTERVIEW (WALK AND TALK) DATA (TABLE 5)

8.3 BOREHOLE LOGS
- 8.3.1 GARTNER LEE ASSOCIATES LIMITED BOREHOLE LOGS
- 8.3.2 SUMMARY OF MINISTRY OF TRANSPORTATION AND COMMUNICATIONS (MTC) BOREHOLE DATA

8.4 SUPPORTING CALCULATIONS AND METHODS

8.5 GLOSSARY OF SELECTED TERMS

8.6 DETAILED FIELD METHODS

8.1 SUMMARY OF WATER WELL DATA

Water well locations are shown in Figure 4 (in map pocket).

Copies of original Water Well Records obtained from the Ontario Ministry of the Environment (MOE) were used for the following data summary and are on file.

Measurements, dimensions, and quantities on the Water Well Records are in Imperial units but are presented in metric units in the summary.

Water well locations (Figure 4) were plotted on 1:10 000 scale maps for this project and elevations were re-estimated, based on the more accurate contours on these maps. Well elevations are above sea level (ASL) and are estimated to the nearest metre.

Well records are arranged in numerical order.

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LE-2M

Sheet 1 of 8

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2328	D.H.O CON. 1 EHS, LOT 6 CITY OF MISSISSAUGA	196	NOV 1960	15.0	24.4	FRESH	9.8	4.6	24.4	0.3	PUBLIC SUPPLY	0.0	1.5	BROWN CLAY
												1.5	9.1	BLUE CLAY
												9.1	18.3	RED SHALE
												18.3	33.5	BLUE SHALE
2329	D.H.O CON. 1. EHS, LOT 6 CITY OF MISSISSAUGA	196	JUL 1961	91.0	DRY	---	7.6	---	--	---	NOT USED	0.0	0.3	CLAY LOAM
												0.3	0.6	SUBSOIL
												0.6	1.5	SANDY CLAY
												1.5	2.7	REDDISH CLAY (HARD)
												2.7	3.4	GREY CLAY(HARD)
												3.4	5.5	BLUE CLAY & SAND (HARD)
												5.5	6.7	RED CLAY (HARD)
												6.7	7.6	RED & GREY SLATE OR SHALE
2330	D.H.O CON. 1 EHS, LOT 6 CITY OF MISSISSAUGA	195	FEB 1961	15.2	21.3 68.5	FRESH FRESH	14.1	7.6	61.0	0.2	PUBLIC SUPPLY	0.0	0.6	TOPSOIL
												0.6	10.1	CLAY & BOULDERS
												10.1	81.1	BLUE SHALE
2331	D.H.O CON. 1 EHS, LOT 6 CITY OF MISSISSAUGA	198	JUN 1962	76.2	4.9	FRESH	8.4	4.9	--	--	PUBLIC SUPPLY	0.0	3.7	BROWN CLAY & STONES
												3.7	6.1	BLUE CLAY & SMALL STONES
												6.1	8.1	RED CLAY & STONES
2332	D.H.O CON. 1 EHS, LOT 6 CITY OF MISSISSAUGA	198	JUN 1962	76.2	DRY	--	--	--	--	--	NOT USED	0.0	0.2	TOPSOIL
												0.2	7.9	BROWN CLAY WITH SOME STONES
												7.9	9.1	BLUE CLAY & RED CLAY
												9.1	9.8	RED CLAY & SHALE LIKE STONE
												9.8		STONE OR SHALE
2333	ANDERSON, W CON. 1 EHS, LOT 7 CITY OF MISSISSAUGA	200	JUN 1953	12.7	12.2	FRESH	12.8	1.5	31.1	0.6	STOCK DOMESTIC	0.6	12.2	RUBBLE & CLAY
												12.2	12.8	RED SHALE
												12.8	31.1	BLUE LIMESTONE
2334	STONE, RON CON. 1 EHS, LOT 7 CITY OF MISSISSAUGA	193	SEP 1961	10.2	20.7	FRESH	11.5	5.5	20.7	0.04	DOMESTIC	0.0	0.6	TOPSOIL
												0.6	11.5	BLUE CLAY
												11.5	21.3	ROCK, RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site : LF-2N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2335	DRAM, FRED CON. 1 EHS, LOT 8 CITY OF MISSISSAUGA	203	APR 1959	10.2	32.0	FRESH	21.3	11.0	25.0	0.1	DOMESTIC	0.0	11.0	DUG WELL
												11.0	25.6	BLUE CLAY
												25.6	31.7	SAND
												31.7	32.3	GRAVEL
2336	SPARLING, I.R CON. 1 EHS, LOT 9 CITY OF MISSISSAUGA	200	MAR 1959	76.2	11.0	FRESH	11.0	4.9	--	0.08	DOMESTIC	0.0	3.7	TOPSOIL, CLAY
												3.7	10.4	GREY CLAY & PEBBLES
												10.4	10.7	SAND AND FINE GRAVEL
												10.7	11.0	COARSE GRAVEL
2337	HOUCK, C.E. CON. 1 EHS, LOT 9 CITY OF MISSISSAUGA	199	MAY 1952	15.2	28.3	FRESH	11.6	7.9	18.3	0.4	DOMESTIC	0.0	11.6	BLUE CLAY GRAVEL
												11.6	28.3	BLUE SHALE
2338	SPARLING, T. CON.1 EHS, LOT 9 CITY OF MISSISSAUGA	200	DEC 1960	76.2	13.7	FRESH	14.0	7.6	--	0.2	DOMESTIC	0.0	3.7	TAN BROWN SOIL
												3.7	13.1	GREY CLAY
												13.1	13.7	GRAVEL
2339	GOLDEN WILLIAM CON.1 EHS, LOT 10 CITY OF MISSISSAUGA	202	MAY 1963	76.2	17.4	FRESH	17.7	7.6	--	0.5	DOMESTIC	0.0	3.7	TAN BROWN SOIL
												3.7	16.8	GREY CLAY
												16.8	17.4	GRAVEL
2340	TIMPSON, A. CON.1 EHS, LOT 11 CITY OF MISSISSAUGA	200	DEC 1965	17.8	36.9 43.9	FRESH SALTY	36.9	7.9	38.1	0.2	DOMESTIC	0.0	5.5	BROWN CLAY
												5.5	10.7	BLUE CLAY
												10.7	21.3	HARDPAN
												21.3	28.0	BLUE CLAY
												28.0	28.3	SAND, GRAVEL, CLAY
												28.3	36.0	BLUE CLAY
												36.0	36.6	HARDPAN
												36.6	43.9	SHALE
														(WELL BACKFILLED TO 39.6 m)
2341	DERRY WEST SCHOOL CON.1 EHS, LOT 11 CITY OF MISSISSAUGA	203	DEC 1956	15.2	20.7 33.2	FRESH SALTY	22.6	7.6	16.8	0.5	PUBLIC SUPPLY	0.0	20.7	PREVIOUSLY DRILLED
												20.7	21.9	BROWN HARDPAN
												21.9	28.3	BLUE CLAY
												28.3	33.2	GREY SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LE-2N

Sheet 3 of 8

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2342	DERRY WEST SCHOOL CON.1 EHS, LOT 11 CITY OF MISSISSAUGA	203	OCT 1953	15.2	18.9	FRESH	19.5	7.3	4.9	--	PUBLIC SUPPLY	0.0 0.3 13.7	0.3 13.7 19.5	TOPSOIL BLUE CLAY SAND, GRAVEL
2343	RUTHERFORD, GEORGE CON.1 EHS, LOT 11 CITY OF MISSISSAUGA	201	MAR 1958	10.2	33.8	FRESH	33.8	7.6	18.3	0.2	DOMESTIC	0.0 12.2 33.8	12.2 33.8 35.7	DRY SAND CLAY AND SAND FINE SAND
2344	VETERE, VIC CON. 1 EHS, LOT 11 CITY OF MISSISSAUGA	205	MAY 1962	10.2	34.7	FRESH	32.6	8.8	34.7	0.1	DOMESTIC	0.0 12.2 32.6	12.2 32.6 34.7	BROWN CLAY COARSE SAND BLUE SHALE
2345	BAIN, ROBERT CON.1 EHS, LOT 11 CITY OF MISSISSAUGA	205	JUL 1965	76.2	19.8	FRESH	20.1	6.1	--	0.2	COM-MERCIAL	0.0 1.5 7.6 16.8 17.1 19.5	1.5 7.6 16.8 17.1 19.5 19.8	BROWN SOIL REDDISH CLAY GREY CLAY FINE SAND GREY CLAY GREY COARSE SAND
2346	HUTCHISON, GORDON CON.1 EHS, LOT 12 CITY OF BRAMPTON	195	OCT 1960	12.7	19.5	FRESH	10.4	6.7	4.8	0.3	DOMESTIC	0.0 0.3 10.4	0.3 10.4 19.5	TOPSOIL BLUE CLAY BLUE SHALE
2347	HUTCHISON, GORDON CON.1 EHS, LOT 12 CITY OF BRAMPTON	195	JUN 1962	76.2	8.2	FRESH	11.6	8.2	--	0.08	DOMESTIC	0.0 3.7 8.2 8.8	3.7 8.2 8.8 11.3	BROWN SOIL GREY CLAY GRAVEL GREY CLAY
2364	McKEE, DAVE CON. 2 EHS, LOT 7 CITY OF MISSISSAUGA	189	MAR 1963	76.2	9.1	FRESH	9.5	4.3	9.1	0.04	DOMESTIC	0.0 5.2 7.3	5.2 7.3 9.4	BROWN CLAY BLUE CLAY AND BOULDERS BLUE SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-214

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2365	PLUMER, NORMAN CON. 2 EHS, LOT 8 CITY OF MISSISSAUGA	195	AUG 1965	76.2	15.2	FRESH	15.2	15.2	--	0.02	DOMESTIC	0.0	3.7	BROWN SOIL
												3.7	15.2	GREY CLAY
												15.2	15.5	GREY SAND
												15.5	23.5	GREY CLAY
												23.5	--	ROCK
2495	MADILL, BEN CON. 1 WHS, LOT 7 CITY OF MISSISSAUGA	197	APR 1950	15.2	7.6	FRESH	2.4	7.6	--	--	STOCK DOMESTIC	0.0	2.4	RED CLAY
												2.4	12.2	RED ROCK
												12.2	30.5	BLUE SHALE, SANDSTONE, LIMESTONE
2496	STEEN, W.N. CON. 1 WHS, LOT 7 CITY OF MISSISSAUGA	192	FEB 1953	10.2	19.5	FRESH	6.1	9.1	9.1	0.3	DOMESTIC	0.0	19.5	BLUE CLAY
												19.5	24.4	GREY SILTY SAND
												24.4	33.2	GRAVEL
2497	MADIL, BEN CON.1 WHS, LOT 7 CITY OF MISSISSAUGA	197	FEB 1953	12.7	ALL THE WAY DOWN	FRESH	--	3.0	45.7	0.3	STOCK DOMESTIC	0.0	30.5	OLD WELL
												30.5	45.7	BLUE SHALE & LIMESTONE
2498	MADILL, BEN CON. 1 WHS, LOT 7 CITY OF MISSISSAUGA	198	MAR 1953	12.7	6.1	FRESH	4.5	1.5	21.3	0.6	STOCK DOMESTIC	0.0	4.6	YELLOW AND RED CLAY
												4.6	13.7	RED MEDINA ROCK
												13.7	21.3	LIMESTONE
2499	SETTER FIELD, JAS CON.1 WHS, LOT 8 CITY OF MISSISSAUGA	201	JUN 1952	10.2	20.7	FRESH	10.7	4.9	--	0.04	DOMESTIC	0.0	0.3	TOPSOIL
												0.3	5.2	SAND
												5.2	21.0	SHALE
2500	SETTER FIELD, JAS CON. 1 WHS. LOT 8 CITY OF MISSISSAUGA	198	JUN 1958	91.4	13.4	FRESH	UNCER-TAIN	7.6	--	0.04	DOMESTIC	0.0	5.5	BROWN SOIL
												5.5	12.8	GREY CLAY WITH PEBBLES
												12.8	13.4	GREY COARSE SAND
2501	KILPATRICK, R.F. CON. 1 WHS, LOT 9 CITY OF MISSISSAUGA	198	JUN 1957	91.4	10.4	FRESH	UNCER-TAIN	3.7	--	0.2	DOMESTIC	0.0	4.6	BROWN SOIL
												4.6	9.8	GREY CLAY WITH PEBBLES
												9.8	10.4	COARSE SAND

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-2N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2502	HANSA CLUB CON.1 WHS, LOT 9 CITY OF MISSISSAUGA	198	NOV 1963	16.8	22.6 32.9	FRESH	21.3	8.2	22.9	0.5	DOMESTIC	0.0 2.7 8.5 20.1 20.7	2.7 8.5 20.1 20.7 34.1	BROWN CLAY GREY CLAY REDDISH BROWN HARDPAN GREY HARDPAN GREY SHALE
2503	McKEE, BOB CON. 1 WHS, LOT 10 CITY OF MISSISSAUGA	198	JUL 1955	10.1	21.0	FRESH	14.9	7.6	18.9	0.4	DOMESTIC	0.0 7.9 10.4 11.6 12.4 14.6	7.9 10.4 11.6 12.4 14.6 23.0	BLUE CLAY SAND, GRAVEL RED SHALE BLUE SHALE BLUE CLAY BLUE SHALE
2504	BP OIL CO. LTD. CON. 1 WHS, LOT 10 CITY OF MISSISSAUGA	203	SEP 1956	15.2	30.5 39.3	FRESH	28.4	6.1	42.7	0.08	COM-MERCIAL	0.0 9.1 21.9 26.8 27.4	9.1 21.9 26.8 27.4 42.7	REDDISH BROWN CLAY BLUE CLAY GRAVEL AND CLAY (DRY) HARDPAN AND BOULDERS BLUE SHALE
2505	HILLOCK, KENNETH P. CON. 1 WHS, LOT 10 CITY OF MISSISSAUGA	203	JUL 1957	91.4	15.2	FRESH	UNCER-TAIN	4.6	--	0.5	DOMESTIC	0.0 6.1 12.2 14.9	6.1 12.2 14.9 15.2	BROWN SOIL BLUE CLAY GREY CLAY WITH PEBBLES GRAVEL
2506	HOFF, ALFRED CON. 1 WHS, LOT 10 CITY OF MISSISSAUGA	198	JUN 1964	76.2	11.3	FRESH	11.3	7.6	--	0.04	DOMESTIC	0.0 2.4 7.6	2.4 7.6 11.3	BROWN SOIL REDDISH CLAY RED SHALE
2507	PELLEJA, L. CON.1 WHS, LOT 10 CITY OF MISSISSAUGA	198	OCT 1965	76.2	12.2	FRESH	14.3	7.6	--	0.04	DOMESTIC	0.0 3.7 10.7	3.7 10.7 14.0	BROWN SOIL GREY CLAY RED SHALE
2508	RICHELLE, A. CON. 1 WHS, LOT 11 CITY OF MISSISSAUGA	203	AUG 1949	15.2	21.6	FRESH	21.6	3.1	3.1	0.8	DOMESTIC	0.0 18.3	18.3 21.6	BLUE CLAY, STONEY GRAVEL

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-2N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2509	MARTIN, WILBER CON. 1 WHS, LOT 11 CITY OF MISSISSAUGA	199	AUG 1955	10.2	19.8	FRESH	15.2	5.5	5.2	0.04	DOMESTIC	0.0	0.6	TOPSOIL, CLAY
												0.6	14.6	BLUE CLAY
												14.6	15.2	SAND AND GRAVEL
												15.2	21.3	RED SHALE
2510	SLOW GROVE, T. CON. 1 WHS, LOT 11 CITY OF MISSISSAUGA	199	AUG 1964	76.2	11.3	FRESH	12.5	--	--	0.04	DOMESTIC	0.0	3.0	BROWN SOIL
												3.0	8.5	GREY CLAY
												8.5	11.3	RED CLAY
												11.3	11.6	COARSE SAND
												11.6	12.2	RED CLAY
												12.2	--	RED SHALE
2511	BALL, G. CON.1 WHS, LOT 12 CITY OF BRAMPTON	208	MAY 1953	14.3	38.4	FRESH	29.5	9.5	38.1	0.2	DOMESTIC	0.0	18.3	BLUE CLAY
												18.3	21.6	QUICKSAND
												21.6	22.3	BROWN FINE SAND
												22.3	24.7	COARSE SAND, GRAVEL
												24.7	29.3	GREY CLAY AND BOULDERS
												29.3	30.2	BROWN SHALE
												30.2	38.4	BLUE SHALE
2512	HEMSTEAD, C. CON. HSW 1, LOT 12 CITY OF BRAMPTON	208	AUG 1956	14.0	23.2	FRESH	22.9	5.2	18.3	0.08	DOMESTIC	0.0	0.3	TOPSOIL
												0.3	18.3	BLUE CLAY
												18.3	22.6	BROWN SAND
												22.6	23.2	GRAVEL
2513	McCRACKEN, W.R. CON. 1 WHS, LOT 12 CITY OF BRAMPTON	205	JUL 1958	10.2	23.2	FRESH	23.2	2.4	12.8	0.2	DOMESTIC	0.0	0.6	BROWN SOIL
												0.6	22.6	SAND AND STONES
												22.6	23.2	GRAVEL
2514	KUIPERS, K. CON. 1 WHS, LOT 12 CITY OF BRAMPTON	205	MAY 1964	76.2	20.1	FRESH	20.4	9.1	--	0.5	DOMESTIC	0.0	3.7	BROWN SOIL
												3.7	19.5	GREY CLAY
												19.5	20.1	COARSE SAND
2551	PARR, J.J CON.2 WHS, LOT 9 CITY OF MISSISSAUGA	185	JUL 1961	12.7	15.2	FRESH	7.3	4.9	14.6	0.1	DOMESTIC	0.0	3.0	BROWN CLAY
												3.0	7.3	BLUE SHALE
												7.3	15.2	BLUE LIMESTONE
												15.2	15.8	CLAY, GRAVEL, SOFT

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LE-2N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2561	GRAY, J. CON. 2 WHS, LOT 11 CITY OF MISSISSAUGA	195	JUL 1956	10.2	13.1	FRESH	3.7	2.6	9.8	0.01	DOMESTIC	0.0	0.3	TOPSOIL
												0.3	3.0	RED CLAY
												3.0	13.1	RED SHALE
2566	BAINE, R. CON.2 WHS, LOT 13 CITY OF BRAMPTON	203	APR 1962	76.2	16.5	FRESH	16.8	3.1	--	0.5	DOMESTIC	0.0	6.1	BROWN SOIL
												6.1	15.8	GREY CLAY
												15.8	16.5	BROWN COARSE SAND
3072	APPLEWOOD LAND SALES CON. 1 WHS, LOT 8 CITY OF MISSISSAUGA	201	FEB 1968	15.9	24.1	FRESH	13.1	5.2	17.7	0.3	STOCK DOMESTIC	0.0	0.3	TOPSOIL
												0.3	12.5	BROWN CLAY AND BOULDERS
												12.5	22.3	RED SHALE
												22.3	25.6	BLUE SHALE
3558	EDELWEISS FARMS LTD. CON. 1 EHS, LOT 9 CITY OF MISSISSAUGA	199	OCT 1970	12.7	19.8 31.7	FRESH	21.3	3.1	29.9	0.08	DOMESTIC	0.0	5.5	BROWN CLAY, STONES
												5.5	9.8	BLUE CLAY, STONES, FIRM
												9.8	19.8	BLUE HARDPAN, HARD
												19.8	31.7	BLUE SHALE
3594	LAVEN, P. CON. 1 EHS, LOT 10 CITY OF MISSISSAUGA	202	MAY 1971	76.2	23.5	FRESH	23.5	6.1	22.6	0.2	DOMESTIC	0.0	3.7	BROWN SOIL
												3.7	22.9	GREY CLAY
												22.9	23.5	GREY SAND
4271	TAVERNA, R. CON.2 WHS, LOT 11 CITY OF MISSISSAUGA	197	JUN 1973	15.9	18.3	FRESH	7.9	5.5	18.4	0.08	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	4.6	BROWN CLAY AND BOULDERS
												4.6	7.3	BLUE CLAY
												7.3	19.8	RED SHALE
4908	PIRRI'S MEADOWVALE MARKET CON. 1 EHS, LOT 11 CITY OF MISSISSAUGA	205	SEP 1975	15.2	19.5	FRESH	19.5	7.9	19.5	0.8	COM-MERCIAL	0.0	5.5	BROWN CLAY STONES, SOFT
												5.5	12.8	GREY CLAY WITH SAND
												12.8	18.3	GREY SAND
												18.3	19.5	BLACK GRAVEL, COARSE SAND
4910	TAVERNA, R. CON. 2 WHS, LOT 11 CITY OF MISSISSAUAGA	198	DEC 1975	15.2	19.5	FRESH	11.0	3.7	61.0	0.8	NOT USED	0.0	0.6	BLACK TOPSOIL, LOOSE
												0.6	6.4	BROWN CLAY, STONES
												6.4	49.4	RED CLAY, SHALE
												49.4	61.0	BLUE SHALE, HARD

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-2N

Sheet 8 of 8

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN	DATE DRILLED YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
5539	PIORCZYNCKI, B. CON. 1 WHS, LOT 11 CITY OF MISSISSAUGA	199	MAY	1978	15.9	16.8	FRESH	7.3	7.9	17.1	0.8	DOMESTIC	0.0	0.3	BLACK TOPSOIL
													0.3	7.0	BROWN CLAY
													7.0	18.3	RED SHALE
5540	FLEMING, J. CON. 1 WHS, LOT 12 CITY OF MISSISSAUGA	199	JUN	1978	15.9	21.9	FRESH	17.7	5.5	5.5	0.8	DOMESTIC	0.0	5.5	BROWN CLAY, STONES
													5.5	14.0	BROWN SAND
													14.0	23.5	RED SHALE
5826	NOVAK AND ULCHOV CON. 1 WHS, LOT 10 CITY OF MISSISSAUGA	198	MAR	1979	15.9	23.2	FRESH	14.9	6.4	23.2	0.8	DOMESTIC	0.0	0.6	BLACK TOPSOIL
													0.6	14.3	BROWN CLAY AND STONES
													14.3	24.4	RED SHALE

8.2 SUMMARY OF SITE INTERVIEW DATA

Water use data from Ecologistics Limited field interview (Walk and Talk) forms is presented in Figure 8 (in map pocket). Water use data were collected from residents on site and on adjacent properties. A copy of the water resources form is attached at the end of this section.

Water use data were augmented with information collected by Gartner Lee Associates Limited staff during discussions with local interest groups and individuals.

Deeper drilled wells are considered to terminate in bedrock where supporting information is available.

Although most of the information was provided in Imperial units, it has been converted to metric units for uniformity with the remainder of the report.

Interview numbers are related to identifications assigned by Ecologistics Limited during the collection of these data.

A copy of the water resources questionnaire is attached at the end of this section.

Copies of the survey forms are on file.

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LF-2N Sheet 1/7

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Wells	Cistern	Remarks
1	Mr. W. Acri	10 City of Mississauga	1 E.H.S	283	✓	✓		Drilled well (No MOE Record) - 9.1 m (30 ft.) deep - supplies household - water quality no good - dries up in summer if used too much Dug / Bored Well (No MOE Record) - 3.0 m (10 ft.) deep - supplies livestock - water quality no good - dries up in summer, if used too much
2	Mr. G. Cox and Mr. W. Golden (Regional Municipality of Peel Shop)	10 City of Mississauga	1 E.H.S.	GLAL field survey	✓			Drilled well (No MOE record) - 15 m (48 ft.) deep - used to wash vehicles - not used for drinking
3	Mr. W. Golden	10 City of Mississauga	1 E.H.S.	GLAL field survey		3		Dug wells (3) (No MOE Record) - all 3 wells approximately 7.5 m (25ft.) deep - wells not used, vacant homestead
4	Dr. I. Sparling	9 City of Mississauga	1 E.H.S	218-2 and GLAL field survey		3		Dug/Bored well (no MOE Record) - 10.1 m (33 ft.) deep - supplies house - water quality hard - never goes dry, approximately 100 years old

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LF-2N Sheet 2/7

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Wells	Cistern	Remarks
4	(cont'd)							Dug/Bored well (MOE well 2336) - 9.1 m (30 ft) deep - supplies livestock - water quality hard Dug/Bored well (MOE Well 2338) - 13.7 m (45 ft) deep (info. from MOE well record)
4	Dr. Sparling			GLAL field survey				Possible drilled well (No MOE record) - 27.4 m (90 ft) deep (approx) - laxative water - completed in 1959 Pond on property
5	Mr. J.A. Todd	9 City of Mississauga	1 W.H.S	241-2 and GLAL field survey	2	✓	✓	Drilled well (No MOE record) - initially dug, deepened by drilling, final depth unknown - supplies household - water quality hard - never goes dry Drilled well (No MOE record) - 9.1 m (30 ft) deep - supplies livestock - water quality hard - never goes dry Dug well (NO MOE Record) - 6.1 m (20 ft) deep - supplies livestock - water quality hard - never goes dry Cistern supplies household pond on property

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site 1F-2N Sheet 3/7

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Wells	Cistern	Remarks
6	Mr. & Mrs. Anacleto	9 City of Mississauga	1 W.H.S	70-1		(2)		Drilled or Dug/Bored well (No MOE Record) - not sure of well type - supplies household - water quality very good - dried up last August Drilled or Dug/Bored well (No MOE Record) - not sure of well type - supplies household - water quality is O.K.
7	Mr. Bunge (German Canadian Club)	9 City of Mississauga	1 W.H.S.	72-1 and GLAL field survey	✓	✓		Drilled well (MOE well 2502) - 30.5 m (100 ft.) deep - water level 3.1 m (10 ft.) from surface - supplies household (i.e. club-house) - water quality tested for bacteria in June 1984, safe for drinking and has never gone dry Dug/Bored well (No MOE Record) - supplies household (i.e. club-house) - has never gone dry Pond on property Very high water table

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LF-2N Sheet 4/7

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Wells	Cistern	Remarks
8	Mr. R.F. Kilpatrick	9 City of Mississauga	1 W.H.S	137-1	✓	✓		Bored well (MOE well 2501) - 10.4 m (34 ft) deep deepened to 155 m (51 ft) - supplies household - water quality hard - has dried up twice in 30 years Drilled well (No MOE record) - 19.2 m (63 ft) deep - water quality salty, corroded pipes - well interference with bored well south of property
9	Mr. K. Gibb and Mr. D. Baker (Edelweiss Farms)	9 City of Mississauga	1 E.H.S	50-2 and GLAL field survey	2	✓		Drilled well (MOE well 2337) - supplies household - water quality bad - runs dry Drilled well (MOE well 3558) - supplies household - water quality poor - runs dry Dug/Bored well (No MOE record) - supplies barn - water level 3.1-3.7 m (10-12 ft) from surface - goes dry Drinking water brought in Pond on property

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LE-2N Sheet 5/7

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Wells	Cistern	Remarks
10	Mr. W. Stocks	8 City of Mississauga	1 E.H.S	74-1		✓		Dug well (No MOE Record) - 8.5 m (28 ft.) deep, stone lined - supplies household - water quality very poor, salty - not used for drinking
11	Mrs. L. McKee	10 City of Mississauga	1 W.H.S	GLAL field survey		✓		Dug/Bored well (No MOE Record) - this well flows seasonally
12	Mr. & Mrs. Golden	10 City of Mississauga	1 E.H.S	26-1 and GLAL field survey		✓		Bored well (MOE well 2339) - 17.4 m (57 ft.) deep - water level approximately 6.1-7.6 m (20-25 ft.) from surface - water quality good, hard - never goes dry - supplies household
13	Mrs. P. Lavin	10 City of Mississauga	1 E.H.S	32-1		✓		Dug/Bored well (MOE well 3594) - 23.5 m (77 ft.) deep - supplies household - water quality good, hard - never goes dry

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LE-2N Sheet 6/7

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Wells	Cistern	Remarks
14	Mr. S. Casar	11 City of Mississauga	1 E.H.S	34-1	✓			Drilled well (MOE well 2340) - 36.5 m (120 ft.) deep - supplies household - water quality excellent, hard - never goes dry
15	Seven Don Holdings	10 City of Mississauga	1 W.H.S.	76-2	✓			Drilled well (No MOE Record) - supplies household - has not gone dry
16	Mr. Aulakh	11 City of Mississauga	1 E.H.S	214-1	✓			Drilled well (MOE well 2343) - supplies household - waste quality good, soft - has never gone dry
17	Mr. E. Scace (tenant)	10 City of Mississauga	1 E.H.S.	IER #3	✓	✓		Drilled well (No MOE record) - supplies household - water quality hard Dug/Bored well (No MOE record) - supplies livestock - water quality hard (Same as No. 1)

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LF-2N Sheet 7/7

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Wells	Cistern	Remarks
18	C. Nugent and H. Rose (Tenants)	8	1 H.S.W.	IER #4		✓		Dug/Bored well (MOE well 2500) - supplies household - water is odour free

Interview Identification Number: _____

PHYSICAL RESOURCES - WATER

We are interested in the water used on this property: where it comes from, its quality, and how much you use.

1. What is this household's source of supply for domestic water? (e.g., drinking, laundry, toilet)

drilled water	☐	Locate on map with symbol Dr-H
dug wells	☐	Locate on map with symbol Du-H
stream water	☐	Locate on map with symbol *SW-H
cistern	☐	Locate on map with symbol *C-H
bottled water	☐	
municipal main	☐	
other, specify		_____

2. What is the water supply for the livestock and irrigation on this property?

drilled wells	☐	Locate on map with symbol Dr-A
dug wells	☐	Locate on map with symbol Du-A
streams or dams	☐	Locate on map with symbol *SW-A
cisterns	☐	
municipal main	☐	
other (e.g., ponds)		_____

3. Are there any streams or ponds on your property?

streams	Yes ☐	No ☐
ponds	Yes ☐	No ☐

4. What can you tell us about the quality of the water

a) you use or drink? (hard, soft, sulphurous, iron, salty, etc.) _____

_____

_____

b) in the streams or ponds? _____

_____

_____

5. Do the wells, cisterns or streams that you use for water supply ever go dry? If so, how often? _____

_____

_____

_____

Interview Identification Number: _____

6. Can you tell us anything about the construction of the wells? (e.g., when they were drilled, depth, type of pump, name of the driller) _____

7. Has any portion of your property been filled or excavated? If so, please show where on the map. (Locate on map with symbol EV.)

8. Do you know where there are any gas or oil wells on your property or the property you farm - in use or abandoned? Please show their locations on the map with the symbol GW.

9. Please tell us about any problems with flooding in the creeks and streams on your property. Please show locations of the flooded areas on the map. (Locate with symbol FA.)

8.3 BOREHOLE LOGS

8.3.1 GARTNER LEE ASSOCIATES LIMITED BOREHOLE LOGS, 1984

8.3.2 SUMMARY OF MINISTRY OF TRANSPORTATION AND COMMUNICATIONS (MTC) BOREHOLE DATA

8.3.1 GARTNER LEE ASSOCIATES LIMITED BOREHOLE LOGS, 1984

Borehole locations are shown in Figure 4 (in map pocket).

Borehole logs are based on field notes which have been verified by the project geologist following re-examination of the samples.

Continuous samples were obtained by advancing a large split tube (8.9 cm x 152 cm) through the hollow stem augers.

Standard penetration tests were performed at 1.5 m intervals and water contents were measured in samples taken from the 'nose-piece' of the standard split spoon sampler.

Textural descriptions are provided for each geologic unit and each deposit is named (in brackets) to indicate its origin.

All material desriptions are based on visual hand sample examination and no laboratory grain size analyses were performed. Textural descriptions are provided under 'Particle Size Classification System' in the Glossary of Selected Terms, Section 8.5.

Borehole elevations are estimated from the 1:10 000 scale base map contours. All elevations are above sea level (ASL) and are estimated to the nearest metre.

The term pebble has been used to describe gravel-sized rock particles within a fine grained matrix.

GEOTECHNICAL NOTES AND ABBREVIATIONS

Standard Penetration Resistance 'N' - The number of blows required to advance a standard split spoon sampler 30 cm into the subsoil, driven by means of a 63.5 kg hammer falling freely a distance of 75 cm.

The consistency of cohesive soils and the relative density or denseness of cohesionless soils are described as follows:

Consistency	'N' Blows per 0.3 m	Denseness	'N' Blows per 0.3 m
Very soft	0-2	Very Loose	0-4
Soft	2-4	Loose	4-10
Firm	4-8	Compact	10-30
Stiff	8-15	Dense	30-50
Very Stiff	15-30	Very Dense	> 50
Hard	> 30		

ABBREVIATIONS

WTPL - Wetter than Plastic Limit

DTPL - Drier than Plastic Limit

APL - About Plastic Limit

Wp - Plastic Limit

WL - Liquid Limit

SS - Split Spoon Sample

T - Split Tube Sample

BOREHOLE NO. GL 1 (2N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** October, 15/84

BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger, Continuous Sampling **GEOLOGIST** A.B./A.C.

GROUND ELEVATION 200 m (approximate) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS
0.3	TOPSOIL: very dark greyish brown clayey silt topsoil.							20 40 60	10 20 30 Wp Wl
	SILT TO CLAYEY SILT TILL: greyish brown silt to clayey silt till, heavily weathered to ±2.5 m with numerous fractures, discoloured fractures at 3.4 m, 3.6-3.7 m, 4.1 m, variable texture 6.0 to 6.7 m, 6.5 to 6.7 m laminated clayey silt till, DTPL to 5.8 m, APL 5.8 to 6.5 m, WTPL 6.5 to 6.7 m, very stiff to hard. (Halton Till)			1	SS	21	11		
				2	SS	33	9		
				3	SS	19	10		
5.7				4	SS	24	12		
	SANDY SILT TO SILT TILL: dark grey sandy silt to silt till, variable, with occasional silt and sand laminae (to 1 cm), larger silt and sand inclusions and zones as noted, sandy zone 8.3 to 8.5 m, silt to medium sand bed 8.6 to 8.7 m, rusty brown discoloured fine sand bed 11.0 to 11.3 m, saturated, very dense. (Lower Till).			5	SS	*	7	* 50/0.08 m	
				6	SS	65	8		
				7	SS	*	8	* 74/0.15 m	
				8	N/A	N/A	N/A	no sample	
				9	SS	*	7	* 56/0.10 m	
				10	SS	*	9	* 75/0.13 m	
				11	SS	*	12	* 55/0.15 m	
				12	SS	*	8	* 58/0.12 m	
	Note: 11.9 m to 34.0 m continuous tube sampling discontinued due to bouldery conditions, split spoon samples only taken below 11.3 m, approximately 1.0 to 1.4 m between split spoons was not recovered.			13	SS	*	15	* 37/0.17 m	
				14	SS	*	11	* 44/0.15 m	
				15	SS	108	9		
				16	SS	*	9	* 94/0.25 m	
				17	SS	63	10		
				18	SS	76	8		

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BOREHOLE NO. GL 1 (2N) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation — DATE October 15/84

BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger, Continuous Sampling — GEOLOGIST A.B./A.C.

GROUND ELEVATION 200 m (approximate) — PROJECT NO. 84- S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
25	SANDY SILT TO SILT TILL: (continued) (Lower Till)			19	SS	79	10		
				20	SS	128	8		
				21	SS	71	11		
				22	SS	*	11	* 58/0.08 m	
				23	SS	*	13	* 70/0.10 m	
34.0	SHALE: dark grey shale, with dolostone interbeds to ± one third of core, shale is soft and thinly bedded, dolostone harder and occasional shale break. (Georgian Bay Formation)								
37.4	Borehole terminated at 37.4 m in shale.								

BOREHOLE NO. GL 2 (2N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation — DATE October 11/84

BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger, Continuous Sampling — GEOLOGIST A.B./A.C.

GROUND ELEVATION 194 m (approximate) — PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
0.3	TOPSOIL: very dark brown clayey silt topsoil, occasional roots								
	SILT TILL: dark grey silt to sandy silt till, weathered to ± 3.0 m, discoloured fractures to 4.7 m, occasional silt to fine sand lamina (to 1 cm), variable below ± 9.0 m, moist to ± 9.0 m, saturated beneath ± 9.0 m, dense to very dense. (Halton Till)			1	SS	26	12		
				2	SS	50	10		
				3	SS	50	10		
				4	SS	*	9	* 50/0.05 m	
				5	SS	56	8		
	- rusty discoloured zone in till 9.3 to 9.4 m			6	SS	36	9		
9.2									
	SILT AND SILT TILL: dark grey silt grading to silt till, laminated to massive, gradational upper and lower boundaries, moist, very dense. (Lower Till)								
10.7									
	SILT TO SANDY SILT TILL: dark grey silt to sandy silt till, variable, increasing sand and shale with depth, moist to ± 9 m, saturated below ± 9 m, dense to very dense. (Lower Till)			7	SS	54	14		
				8	SS	65	8		
				9	SS	58	9		
	- increasing sand content in till			10	SS	53	8		
	- 15.5 to 15.6 m sandy zone in till with rusty discolouration								
	- becoming silty sand till			11	SS	40	8		
	- fractures with rusty discolouration (16.7 to 16.8 m)			12	SS	48	10		
	- fractures with rusty discolouration (19.3 to 19.5 m)			13	SS	*	7	* 62/0.15 m	
	- sand interbeds to 4 cm (20.2 to 20.4 m)			14	SS	*	8	* 58/0.15 m	
	- increasing grey shale content in till (to bedrock) (±22.0 m)			15	SS	*	9	* 50/0.15 m	
22.8									
	SHALE: dark grey shale, with dolostone hard layers 10 to 15 cm thick, softer thin bedded shale (±2/3 of core) (Georgian Bay Formation)								
25.4									

Borehole terminated at 25.4m in shale

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BOREHOLE NO. GL 3 (2N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** October 20/84

BOREHOLE TYPE 108 mm I.D.Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 194 m(approximate) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS
0.3	TOPSOIL: brown clayey silt topsoil, with roots, twigs and straw								
	SILT TILL: brown to dark grey silt to sandy silt till, heavily weathered to ± 1.0 m, fractures common to 2.7 m, colour change brown to grey at 3.5 m, rusty fine sand laminae (to 1 cm) in till 3.2 to 3.5 m, rusty discoloured fractures 4.0 to 4.2 m, moist to 3.5 m, saturated below 3.5 m, dense to very dense. (Halton Till)			1	SS	76	10		
				2	SS	68	10		
				3	SS	35	10		
5.0									
5.9	SILTY CLAY TO CLAYEY SILT: grey silty clay to clayey silt, laminated to massive, with pebbles to 2 cm, till-like in places, very stiff.			4	SS	18	21		
	SANDY SILT TILL: dark grey sandy silt to silt till, saturated, compact to very dense. (Lower Till)			5	SS	29	11		
				6	SS	*	7	* 62/0.15 m	
				7	SS	*	7	* 53/0.08 m	
				8	SS	74	8		
	- becoming variable at ±13.0 m, occasional silt or fine sand lamina to 2 cm, till matrix becoming sandier with depth			9	SS	N/A	9	boulder - no sample	
				10	SS	*	8	* 58/0.15 m	
	- rusty discoloured fractures 16.0 to 16.1 m - till grading to a silty sand till (±16.5 m)			11	SS	93	8		
				12	SS	81	7		
18.4	- lower contact gradational								
	FINE TO MEDIUM SAND: grey fine to medium sand, with silt and pebbles, laminated, very dense, saturated.			13	SS	93	18		
20.9									
	SANDY SILT TILL: dark grey sandy silt to silty sand till, laminated to massive, occasional silt and fine sand laminae to 1.5 cm, saturated, very dense. (Lower Till)			14	SS	*	5	* 55/0.08 m	
23.3				15	SS	*	13	* 60/0.10 m	
	FINE TO MEDIUM SAND: grey pebbley fine to medium sand, saturated, very dense								
24.3									
	SANDY SILT TILL: dark grey sandy silt till, saturated, very dense. (Lower Till)			16	SS	*	16	* 66/0.15 m	

PENETRATION RESISTANCE BLOWS/0.3m: 20 40 60

WATER CONTENT % / COMMENTS: 10 20 30 (Wp — Wl)

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BOREHOLE NO. GL 3 (2N) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE October 20/84

BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 194 m (approximate) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
	SANDY SILT TILL: (continued) (Lower Till)			17	SS	*	21	* 60/0.15 m	
27.1				18	SS	*	7	* 67/0.15 m	
29.4	DOLOSTONE AND SHALE: dark grey interbedded dolostone and shale, dolostone is fine to medium grained in 10 to 15 cm (average) thick beds, shale is fine bedded and weathered, crumbly, dolostone slightly greater than shale. (Georgian Bay Formation)								
	Borehole terminated at 29.4 m in shale								

BOREHOLE NO. GL 4 (2N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation — DATE October 9/84

BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger, Continuous Sampling — GEOLOGIST AB/AC

GROUND ELEVATION 199 m (approximate) — PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.5	TOPSOIL: very dark brown silt topsoil, numerous roots								
	SILT TILL: yellowish brown to dark grey silt till, trace of clay, heavily weathered to ± 1.3 m, fractures common to 2.8 m, numerous fractures with discolouration 3.3 to 3.9 m, brown to grey colour change at ± 4.3 m, rusty coloured fracture at 4.3 m and 4.7 m, hard to very stiff. (Halton Till)			1	SS	35	14		
				2	SS	40	10		
5.1				3	SS	28	10		
	SILTY SAND TILL: dark grey silty sand till, variable, very little clay content, sharp upper boundary, gradational lower boundary, wet to 5.9 m, saturated below 5.9 m, very dense. (Lower Till)			4	SS	77	8		
7.9				5	SS	82	11		
8.8	CLAYEY SILT: grey clayey silt, with fine sand laminae, occasional small pebble (to 1 cm), laminated.			6	SS	30	16		
	SILTY FINE TO MEDIUM SAND: grey silty fine to medium sand, occasional pebble to 6 cm, laminated, gradational upper and lower boundaries, saturated, very dense.			7	SS	*	13	* 50/0.15 m	
				8	SS	*	14	* 55/0.15 m	
14.4				9	SS	*	18	* 70/0.13 m	
	SILTY SAND TILL: dark grey silty sand till, variable, loose structure in places, becomes sandy silt till near base, gradational upper and lower boundaries, saturated, very dense. (Lower Till)			10	SS	*	12	* 58/0.08 m	
17.0				11	SS	*	11	* 60/0.13 m	
	INTERBEDDED FINE SAND AND SILTY SAND TILL: dark grey interbedded fine sand and silty sand till, interbedded and gradational, approximately equal proportions till and sand, till contains numerous sand layers and laminae, sand is often silty and till-like, interbeds commonly 0.1 to 1 m in thickness, gradational from above till unit and grades into underlying bedrock, saturated, very dense. (Lower Till)			12	SS	*	14	* 50/0.10 m	
				13	SS	*	17	* 50/0.10 m	
				14	SS	*	11	* 70/0.13 m	
				15	SS	*	17	* 50/0.10 m	
				16	SS	*	14	* 60/0.10 m	

BOREHOLE NO. GL 4 (2N) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE October 9/84

BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 199 m (approximate) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) Wp — Wl / COMMENTS
	INTERBEDDED FINE SAND AND SILTY SAND TILL (continued)			17	SS	*	17	* 58/0.10 m	
	- small black spots and organic smell noted 25.6 to 25.9 m and 27.1 to 27.3 m			18	SS	*	11	* 60/0.10 m	
28.0									
	LIMESTONE AND SHALE: grey argillaceous limestone with shale interbeds, approximately 3/4 limestone, with distinct shale bands, fossiliferous zones. (Georgian Bay Formation)								
31.4									
	Borehole terminated at 31.4 m in limestone.								

BOREHOLE NO. GL 5 (2N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation — DATE October 17/84

BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger, Continuous Sampling — GEOLOGIST AB/AC

GROUND ELEVATION 203 m (approximate) — PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
0.4	TOPSOIL: very dark greyish brown silt topsoil, trace of clay, occasional root			1	SS	49	11		
	SILT TILL: brown to dark grey silt to clayey silt till, heavily weathered to ± 1.5 m, numerous fractures to ± 2.4 m, rusty coloured fine sand laminae (1 cm) at 1.9 m colour change to grey at ± 3.3 m, rusty coloured fractures 4.0 to 4.2 m, grey inclusion of very fine sand 6.6 to 6.7 m, 20 cm bed of fine sandy silt on lower boundary, very stiff to hard. (Halton Till)			2	SS	68	10		
				3	SS	41	11		
				4	SS	31	12		
				5	SS	37	14		
				6	SS	43	10		
11.0				7	SS	22	10		
	SILTY SAND TILL: dark grey silty sand till, silty to ± 13 m, sharp increase in sand content below 15.7 m, also more pebbles (to 10 cm) and occasional fine sand lamina (to 1 cm), gradational lower boundary, saturated, very dense. (Lower Till)			8	SS	93	6		
				9	SS	*	9	* 68/0.15 m	
				10	SS	*	8	* 61/0.15 m	
				11	SS	*	14	* 53/0.15 m	
17.6				12	SS	*	10	* 50/0.08 m	
	VERY FINE SAND TO SILT: dark grey very fine sand to silt, with beds of silt till to 20 cm and till-like zones, gradational to till above and below, saturated, very dense.			13	SS	*	12	* 60/0.10 m	
20.0				14	SS	*	10	* 55/0.08 m	
	SILTY SAND TILL: dark grey silty sand to sandy silt till, numerous pebbles 5 to 10 cm, gradational upper and lower boundaries, saturated, very dense. (Lower Till)			15	SS	N/A	7	no split spoon sample	
23.2									
	SILT: dark grey silt, with sand and fine sand laminae to 1 cm, laminated, occasional small (<1 cm) pebbles, saturated, very dense.			16	SS	*	14	* 75/0.10 m	

BOREHOLE NO. GL 5 (2N) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** October 17/84

BOREHOLE TYPE 108 mm I.D. Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 203 m (approximate) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) Wp — Wl / COMMENTS
25.3									
	SANDY TO CLAYEY SILT TILL: dark grey sandy to clayey silt till, variable, numerous grey shale and limestone fragments increasing with depth, gradational to underlying bedrock, saturated, very dense. (Lower Till)			17	SS	*	6	* 60/0.10 m	
				18	SS	*	8	* 58/0.15 m	
				19	SS	*	5	* 61/0.08 m	
30.5									
	LIMESTONE WITH SHALE: grey limestone with numerous shale partings, medium grained limestone with fossils, numerous breaks in core. (Georgian Bay Formation)								
32.6									
	Borehole terminated at 32.6 m in limestone.								

BOREHOLE NO. GL 6 (2N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** October 23/84

BOREHOLE TYPE 108 mm I.D.Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 197 m (approximate) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS
0.2	TOPSOIL: very dark brown clayey silt topsoil, occasional roots.								
	SILT TILL: yellowish brown to dark grey silt to clayey silt till, heavily weathered to 1.9 m, numerous discoloured fractures to 4.1 m, rusty fractures at 6.1 m, fine sand 7.1 to 7.2 m. Very stiff to hard. (Halton Till)			1	SS	30	11		
				2	SS	40	10		
				3	SS	22	8		
				4	SS	24	12		
7.2				5	SS	28	10		
	SILTY SAND TILL: dark grey to dark reddish grey silty sand to sandy silt till, variable, sandy zones (to 10 cm) occasional in till, occasional sand bed to 5 cm, medium to fine sand bed with gradational boundaries 13.6 to 14.8 m, numerous red and grey shale fragments below ± 15 m, increasing pebble and clay content in till below ± 16 m depth, gradational to bedrock, saturated, compact to very dense. (Lower Till)			6	SS	43	10		
				7	SS	78	8		
				8	SS	*	9	* 51/0.15 m	
				9	SS	*	9	* 55/0.08 m	
	} - medium to fine sand			10	SS	*	12	* 53/0.15 m	
				11	SS	91	11		
				12	SS	*	10	* 61/0.15 m	
				13	SS	*	9	* 75/0.05 m	
20.8				14	SS	*	N/A	* 50/0.00 m (no sample)	
	LIMESTONE WITH SHALE: grey limestone with numerous shale partings, fossiliferous fine to medium grained limestone with numerous shale zones and interbeds. (Georgian Bay Formation)								
23.8	Borehole terminated at 23.8 m in shale.								

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8.3.2 SUMMARY OF MINISTRY OF TRANSPORTATION AND COMMUNICATIONS (MTC) BOREHOLE DATA

Borehole elevations are provided to the nearest tenth of a foot or to the nearest tenth of a metre in the original data. Elevations have been converted to metric and/or rounded to the nearest metre in Figure 4.

8.3.2 SUMMARY OF MINISTRY OF TRANSPORTATION AND COMMUNICATIONS (MTC) BOREHOLE DATA

Site: LF-2N
Sheet 1 of 7

MTC BOREHOLE No.	LOCATION	GROUND ELEVATION (m ASL)	FROM	TO	MATERIALS DESCRIPTION	COMMENTS
MTC 1 WP-33-73-01 BH#2	CON 1 E.H.S. LOT 5 CITY OF MISSISSAUGA	191	0.0	2.6	CLAYEY SILT FILL WITH SOME SAND TRACE OF GRAVEL AND ORGANICS	
			2.6	3.4	HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND & GRAVEL (GLACIAL TILL)	HARD
			3.4	4.6	WEATHERED SHALE	
			4.6	7.8	SHALE	
MTC 2 WP-33-73-01 BH#3	CON 2 E.H.S. LOT 5 CITY OF MISSISSAUGA	194	0.0	3.7	HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND & GRAVEL (GLACIAL TILL)	HARD
			3.7	5.9	WEATHERED SHALE	
			5.9	11.6	SHALE	
MTC 3 WP-54-82-02 B.H.1	CON. 1 WHS, LOT 6 CITY OF MISSISSAUGA	195	0.0	4.4	FILL, SILTY CLAY, SOME SAND, TRACE GRAVEL, TRACE ORGANICS	STIFF TO VERY STIFF
			4.4	6.9	SHALE BEDROCK, VERY WEATHERED, RED	
MTC 4 WP-54-82-02 B.H.2	CON.1 WHS, LOT 6 CITY OF MISSISSAUGA	193	0.0	1.4	FILL, SILTY CLAY, SOME SAND TRACE GRAVEL	STIFF TO VERY STIFF
			1.4	4.4	HETEROGENOUS MIXTURE, SILTY CLAY, SOME SAND & GRAVEL. (GLACIAL TILL)	HARD
			4.4	6.5	SHALE BEDROCK VERY WEATHERED. RED	
MTC 5 WP 54-82-02 B.H.3	CON.1 WHS, LOT 6 CITY OF MISSISSAUGA	196	0.0	4.7	FILL, SILTY CLAY WITH SAND, SOME GRAVEL - ASPHALTIC CONCRETE	STIFF TO VERY STIFF
			4.7	7.0	ORGANIC MATTER, HETEROGENOUS MIXTURE SILTY CLAY, SOME SAND & GRAVEL	HARD
			7.0	9.4	SHALE BEDROCK VERY WEATHERED RED	
MTC 6 WP-54-82-02 B.H.4	CON. 1 EHS, LOT 6 CITY OF MISSISSAUGA	200	0.0	7.7	FILL, FINE TO MEDIUM SAND, SOME SILT. SILTY CLAY WITH SAND, SOME GRAVEL, TRACES OF ORGANIC MATTER. SILTY SAND	COMPACT FIRM TO VERY STIFF
			7.7	9.8	ORGANIC MATTER HETEROGENOUS MIXTURE, SILTY CLAY, SOME SAND AND GRAVEL (GLACIAL TILL)	HARD
			9.8	15.3	SHALE BEDROCK VERY WEATHERED, RED	

8.3.2 SUMMARY OF MINISTRY OF TRANSPORTATION AND COMMUNICATIONS (MTC) BOREHOLE DATA

Site: LF-2N
Sheet 2 of 7

MTC BOREHOLE No.	LOCATION	GROUND ELEVATION (m ASL)	FROM	TO	MATERIALS DESCRIPTION	COMMENTS
MTC 7 WP-54-82-02 B.H.5	CON. 1 EHS, LOT 6 CITY OF MISSISSAUGA	200	0.0	7.9	FILL, FINE TO MEDIUM SAND, SOME SILT. SILTY SAND. SILTY CLAY WITH SAND, SOME GRAVEL, TRACES OF ORGANIC MATTER	LOOSE TO DENSE STIFF TO VERY STIFF
			7.9	10.7	HETEROGENOUS MIXTURE OF SILTY CLAY, SOME SAND & GRAVEL (GLACIAL TILL)	HARD
			10.7	12.4	SHALE BEDROCK, VERY WEATHERED RED	
MTC 8 WP-54-82-02 B.H.6	CON. 1 EHS, LOT 6 CITY OF MISSISSAUGA	200	0.0	7.8	FILL, FINE TO MEDIUM SAND, SOME SILT. SILT SILTY SAND, SILTY CLAY WITH SAND, SOME GRAVEL	COMPACT STIFF
			7.8	10.9	HETEROGENEOUS MIXTURE OF SILTY CLAY, SOME SAND & GRAVEL (GLACIAL TILL)	HARD
			10.9	12.0	SHALE BEDROCK VERY WEATHERED RED	
MTC 9 WP-54-82-02 B.H.7	CON. 1 WHS, LOT 6 CITY OF MISSISSAUGA	193	0.0	1.4	FILL, SITLY CLAY WITH SAND, SOME GRAVEL.	STIFF
			1.4	3.5	HETEROGENOUS MIXTURE OF SILTY CLAY, SOME SAND & GRAVEL (GLACIAL TILL)	HARD
			3.5	6.6	SHALE BEDROCK VERY WEATHERED RED	
MTC 10 WP-54-82-02 B.H.8	CON.1 WHS, LOT 6 CITY OF MISSISSAUGA	193	0.0	1.4	FILL, FINE TO MEDIUM SAND, TRACE CLAY	COMPACT
			1.4	2.5	SILTY CLAY, SOME SAND & GRAVEL (GLACIAL TILL)	HARD
			2.5	4.4	SHALE BEDROCK VERY WEATHERED RED	
MTC 11 WP-54-82-05 B.H.#1	CON 2 E.H.S. LOT 6 CITY OF MISSISSAUGA	197	0.0	0.5	GRAVELLY SAND FILL	
			0.5	5.2	REDDISH AND BROWN, SILTY CLAY FILL WITH SOME SAND AND TRACES OF GRAVEL AND COBBLES. SOME ORGANIC MATERIALS MIXED IN.	
			5.2	5.8	DARK GREY TO BLACK, ORGANIC SILTY CLAY	TRACES OF DECAYED ROOTS
			5.8	7.2	LIGHT GREY, SILTY CLAY TILL WITH SOME SAND LENSES.	HARD. REDDISH WITH SHALE FRAGMENTS BELOW 6.8 m

8.3.2 SUMMARY OF MINISTRY OF TRANSPORTATION AND COMMUNICATIONS (MTC) BOREHOLE DATA

Site: LF-2N
Sheet 3 of 7

MTC BOREHOLE No.	LOCATION	GROUND ELEVATION (m ASL)	FROM	TO	MATERIALS DESCRIPTION	COMMENTS
MTC 12	CON 2 E.H.S. LOT 6	193	0.0	0.2	TOPSOIL	
WP-54-82-05	CITY OF MISSISSAUGA		0.2	2.7	BROWN SILTY CLAY TILL	HARD, REDDISH WITH SHALE
B.H.#2			2.7	5.6	REDDISH SHALE WITH SOME GREYISH SHALE AND LIMSTONE SEAMS	FRAGMENTS BELOW 2.1 m
MTC 13	CON 2 E.H.S. LOT 6	198	0.0	0.5	GRAVELLY SAND FILL	
WP-54-82-05	CITY OF MISSISSAUGA		0.5	6.1	MULTICOLOURED SILTY CLAY FILL WITH SOME SAND AND TRACES OF GRAVEL. TRACES OF ORGANIC MATERIAL MIXED IN	
B.H.#3			6.1	8.0	BROWNISH SILTY CLAY TILL.	HARD, TRACES OF ORGANICS AND SOME SAND LENSES FROM 6.1 TO 6.6 m. REDDISH WITH SHALE FRAGMENTS BELOW 7.3 m
			8.0	8.5	REDDISH WEATHERED SHALE	
MTC 14	CON 2 E.H.S. LOT 6	192	0.0	0.1	TOPSOIL	
WP-54-82-05	CITY OF MISSISSAUGA		0.1	2.1	REDDISH SILTY CLAY TILL	STIFF TO HARD SHALE
B.H.#4			2.1	5.6	REDDISH SHALE, SOME GREYISH SHALE AND LIMESTONE SEAMS	FRAGMENTS BELOW 1.3 m
MTC 15	CON 2 E.H.S. LOT 5	191	0.0	0.8	ASPHALT, CONCRETE AND SANDY GRAVEL FILL	
WP-54-82-05	CITY OF MISSISSAUGA					
B.H.#5			0.8	1.8	REDDISH, SILTY CLAY TILL WITH SHALE FRAGMENTS	HARD
			1.8	5.8	REDDISH SHALE, SOME GREYISH SHALE AND LIMESTONE SEAMS	
MTC 16	CON 2 E.H.S. LOT 5	191	0.0	0.8	ASPHALT, CONCRETE AND SANDY GRAVEL FILL	
WP-54-82-05	CITY OF MISSISSAUGA					
B.H.#6			0.8	1.6	REDDISH SILTY CLAY TILL WITH SHALE FRAGMENTS	PROBABLE BEDROCK AT 1.6 m
MTC 17	CON 2 E.H.S. LOT 5	198	0.0	0.1	TOPSOIL	
WP-54-82-05	CITY OF MISSISSAUGA		0.1	5.8	MULTICOLOURED SILTY CLAY FILL WITH SOME GRAVEL, TRACES OF ORGANIC POCKETS	
B.H.#7			5.8	6.5	DARK GREY/BLACK, ORGANIC SILTY CLAY	VERY STIFF
			6.5	7.4	REDDISH SILTY CLAY TILL WITH TRACES OF ORGANICS	SHALE FRAGMENTS BELOW 7.2 m

8.3.2 SUMMARY OF MINISTRY OF TRANSPORTATION AND COMMUNICATIONS (MTC) BOREHOLE DATA

Site: LF-2N

MTC BOREHOLE No.	LOCATION	GROUND ELEVATION (m ASL)	FROM	TO	MATERIALS DESCRIPTION	COMMENTS
MTC 18	CON 2 E.H.S. LOT 5	192	0.0	0.1	TOPSOIL	
WP-54-82-05	CITY OF MISSISSAUGA		0.1	2.0	REDDISH SILTY CLAY TILL WITH SHALE FRAGMENTS	HARD
B.H.#8			2.0	5.7	REDDISH SHALE SOME GREYISH SHALE AND LIMESTONE SEAMS	WEATHERED FROM 3.0 TO 3.7 m
MTC 19	CON 2 E.H.S. LOT 5	196	0.0	0.6	GRAVELLY SAND FILL	
WP-54-82-05	CITY OF MISSISSAUGA		0.6	3.7	MULTICOLOURED SILTY CLAY FILL, WITH SOME SAND AND GRAVEL.	
B.H. #9			3.7	4.1	DARK GREY/BLACK, ORGANIC SILTY CLAY	
			4.1	6.2	GREYISH SILTY CLAY TILL	HARD. SOME ORGANICS FROM FROM 4.1 TO 4.4 m. REDDISH WITH SHALE FRAGMENTS BELOW 5.5 m
MTC 20	CON 2 E.H.S. LOT 5	195	0.0	0.2	TOPSOIL	
WP-54-82-05	CITY OF MISSISSAUGA		0.2	3.6	REDDISH, SITLY CLAY TILL.	VERY STIFF TO HARD.
B.H.#10			3.6	5.5	REDDISH SHALE SOME GREYISH SHALE AND LIMESTONE SEAMS.	SHALE FRAGMENTS BELOW 2.1 m. WEATHERED FROM 3.6 TO 4.0 m.
MTC 21	CONC 2 E.H.S. LOT 5	195	0.0	0.1	TOPSOIL	
WP-54-82-05	CITY OF MISSISSAUGA		0.1	0.5	GRAVELLY SAND FILL	
B.H. #11			0.5	3.0	MULTICOLOURED SILTY CLAY FILL WITH SOME SAND AND GRAVEL	
			3.0	4.6	GREYISH SILTY CLAY TILL	VERY STIFF TO HARD LAYERED FROM 3.0 TO 3.4 m. REDDISH WITH SHALE FRAGMENTS BELOW 4.0 m
MTC 22	CONC 2 E.H.S. LOT 5	193	0.0	0.2	TOPSOIL	
WP-54-82-05	CITY OF MISSISSAUGA		0.2	2.9	REDDISH, SILTY CLAY TILL WITH SHALE FRAGMENTS	HARD
B.H.#12			2.9	5.8	REDDISH SHALE SOME GREYISH SHALE AND LIMESTONE SEAMS.	

8.3.2 SUMMARY OF MINISTRY OF TRANSPORTATION AND COMMUNICATIONS (MTC) BOREHOLE DATA

Site: LF-2N
Sheet 5 of 7

MTC BOREHOLE No.	LOCATION	GROUND ELEVATION (m ASL)	FROM	TO	MATERIALS DESCRIPTION	COMMENTS
MTC 23 WP-68-61 B.H.#6	CON 1 E.H.S. LOT 6 CITY OF MISSISSAUGA	193	0.0 0.6	0.6 2.9	SAND AND GRAVEL FILL CLAYEY SILT WITH SAND AND GRAVEL	 COMPACT TO VERY DENSE
MTC 24 WP-68-61 B.H. #7	CON 1 E.H.S. LOT 6 CITY OF MISSISSAUGA	193	0.0 0.3	0.3 3.2	SAND AND GRAVEL FILL CLAYEY SILT WITH SAND AND GRAVEL	 COMPACT TO VERY DENSE
MTC 25 WP-87-78-00 B.H.#61	CON 2 W.H.S. LOT 13 CITY OF BRAMPTON	203	0.0	10.9	BROWN, SANDY SILT, TRACE CLAY AND GRAVEL	COMPACT TO VERY DENSE GREY BELOW 4.6 m
MTC 26 WP-87-78-00 B.H. #74S	CON 2 E.H.S. LOT 12 CITY OF BRAMPTON	191	0.0	8.2	SANDY SILT, TRACE CLAY, GRAVEL AND COBBLES	VERY DENSE
MTC 27 WP-87-78-00 B.H.#102	CON 1 E.H.S. LOT 12 CITY OF BRAMPTON	206	0.0 10.4	10.4 15.7	BROWN,HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND AND GRAVEL (GLACIAL TILL) HETEROGENEOUS MIXTURE OF SILT, SAND SAND AND GRAVEL(GLACIAL TILL)	VERY STIFF TO HARD GREY BELOW 3.1 m VERY DENSE
MTC 28 WP-87-78-00 B.H. #103	CON 2 E.H.S. LOT 13 CITY OF BRAMPTON	195	0.0	3.5	HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND & GRAVEL (GLACIAL TILL)	VERY HARD. PROBABLE BEDROCK AT 3.5 m
MTC 29 WP-87-78-00 B.H. #110	CON. 1 W.H.S. LOT 13 CITY OF BRAMPTON	197	0.0 2.3	2.3 12.5	SILTY SAND, TRACE CLAY HETEROGENEOUS MIXTURE OF SILTY CLAY, SAND AND GRAVEL (GLACIAL TILL)	LOOSE TO COMPACT HARD TO VERY DENSE
MTC 30 WP103-69-08 B.H.#1(1)	CON. 2 E.H.S. LOT 11 CITY OF MISSISSAUGA	185	0.0	9.3	BROWN HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND AND GRAVEL (GLACIAL TILL)	VERY STIFF TO HARD GREY BELOW 2.4 m
MTC 31 WP103-69-08 B.H.#1(2)	CON. 2 E.H.S. LOT 11 CITY OF MISSISSAUGA	185	0.0	8.4	BROWN HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND AND GRAVEL (GLACIAL TILL)	VERY STIFF TO HARD GREY BELOW 2.5 m

8.3.2 SUMMARY OF MINISTRY OF TRANSPORTATION AND COMMUNICATIONS (MTC) BOREHOLE DATA

Site: LF-2N

MTC BOREHOLE No.	LOCATION	GROUND ELEVATION (m ASL)	FROM	TO	MATERIALS DESCRIPTION	COMMENTS
MTC 32 WP103-69-08 B.H.#2(1)	CON. 2 E.H.S. LOT 12 CITY OF BRAMPTON	189	0.0	7.5	BROWN, HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND AND GRAVEL (GLACIAL TILL)	VERY STIFF TO HARD GREY BELOW 2.7 m
MTC 33 WP103-69-08 B.H.#2(2)	CON. 2 E.H.S. LOT 12 CITY OF BRAMPTON	190	0.0	5.7	BROWN, HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND AND GRAVEL (GLACIAL TILL)	STIFF TO HARD. GREY BELOW 2.5 m
MTC 34 WP103-69-13 B.H.#1	CON. 2 E.H.S. LOT 8 CITY OF MISSISSAUGA	188	0.0	13.7	BROWN, HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND AND GRAVEL (GLACIAL TILL)	STIFF TO HARD. GREY BELOW 3.9 m PROBABLE BEDROCK AT 13.7 m
MTC 35 WP103-69-13 B.H.#2	CON. 2 E.H.S. LOT 8 CITY OF MISSISSAUGA	188	0.0	9.3	BROWN, HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND AND GRAVEL (GLACIAL TILL)	STIFF TO HARD. GREY BELOW 3.3 m
MTC 36 WP103-69-13 B.H.#3	CON. 2 E.H.S. LOT 8 CITY OF MISSISSAUGA	186	0.0	13.6	BROWN, HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND AND GRAVEL (GLACIAL TILL)	STIFF TO HARD GREY BELOW 3.3 m PROBABLE BEDROCK AT 13.6 m
MTC 37 WP103-69-13 B.H.#4	CON. 2 E.H.S. LOT 8 CITY OF MISSISSAUGA	186	0.0	9.3	BROWN, HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND AND GRAVEL (GLACIAL TILL)	STIFF TO HARD. GREY BELOW 3.1 m
MTC 38 WP103-69-13 B.H.#5	CON. 2 E.H.S. LOT 8 CITY OF MISSISSAUGA	186	0.0	9.3	BROWN, HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND AND GRAVEL (GLACIAL TILL)	STIFF TO HARD GREY BELOW 2.9 m
MTC 39 WP103-69-13 B.H.#6	CON. 2 E.H.S. LOT 8 CITY OF MISSISSAUGA	186	0.0	13.4	BROWN, HETEROGENEOUS MIXTURE OF CLAYEY SILT, SAND AND GRAVEL (GLACIAL TILL)	STIFF TO HARD. GREY BELOW 3.0 m PROBABLE BEDROCK AT 13.4 m
MTC 40 WP127-66-22 B.H.#1	CON. 2 E.H.S. LOT 5 CITY OF MISSISSAUGA	184	0.0	2.9	BROWN, HETEROGENEOUS MIXTURE OF SILTY CLAY, SOME SAND AND GRAVEL (GLACIAL TILL)	STIFF TO HARD
			2.9	9.3	DARK GREY INTERBEDDED SHALE AND LIMESTONE.	

8.3.2 SUMMARY OF MINISTRY OF TRANSPORTATION AND COMMUNICATIONS (MTC) BOREHOLE DATA

Site: LF-2N
Sheet 7 of 7

MTC BOREHOLE No.	LOCATION	GROUND ELEVATION (m ASL)	FROM	TO	MATERIALS DESCRIPTION	COMMENTS
MTC 41 WP127-66-22 B.H.#2	CON. 2 E.H.S. LOT 5 CITY OF MISSISSAUGA	184	0.0	2.6	BROWN, HETEROGENEOUS MIXTURE OF SILTY CLAY WITH SOME SAND AND GRAVEL (GLACIAL TILL)	STIFF TO HARD PROBABLE BEDROCK AT 2.6 m
MTC 42 WP127-66-22 B.H.#3	CON. 2 E.H.S. LOT 5	184	0.0	1.7	BROWN, HETEROGENEOUS MIXTURE OF CLAYEY SILT, SOME SAND AND GRAVEL (GLACIAL TILL)	STIFF TO HARD PROBABLE BEDROCK AT 1.7 m
MTC 43 WP127-66-22 B.H.#4	CON. 2 E.H.S. LOT 5 CITY OF MISSISSAUGA	184	0.0	1.3	BROWN, HETEROGENEOUS MIXTURE OF CLAYEY SILT, SOME SAND AND GRAVEL (GLACIAL TILL)	
			1.3	9.3	DARK GREY, INTERBEDDED SHALE AND LIMESTONE	BEDROCK WEATHERED TO 2.7 m
MTC 44 WP127-66-22 B.H.#5	CON. 2 E.H.S. LOT 5 CITY OF MISSISSAUGA	185	0.0	1.8	BROWN, HETEROGENEOUS MIXTURE OF CLAYEY SILT, SOME SAND AND GRAVEL (GLACIAL TILL)	STIFF TO VERY STIFF
			1.8	3.0	DARK GREY SHALE	WEATHERED
			3.0	9.1	DARK GREY, INTERBEDDED SHALE AND LIMESTONE	
MTC 45 WP127-66-22 B.H.#6	CON. 2 E.H.S. LOT 5 CITY OF MISSISSAUGA	185	0.0	2.3	BROWN, HETEROGENEOUS MIXTURE OF CLAYEY SILT, SOME SAND AND GRAVEL (GLACIAL TILL)	STIFF TO HARD PROBABLE BEDROCK AT 2.3 m
MTC 46 WP127-66-22 B.H.#7	CON. 2 E.H.S. LOT 5 CITY OF MISSISSAUGA	185	0.0	2.3	BROWN, HETEROGEOUS MIXTURE OF CLAYEY SILT, SOME SAND AND GRAVEL (GLACIAL TILL)	STIFF TO HARD PROBABLE BEDROCK AT 2.3 m
MTC 47 WP127-66-22 B.H.#8	CON, 2 E.H.S. LOT 5 CITY OF MISSISSAUGA	185	0.0	1.8	BROWN, HETEROGENEOUS MIXTURE OF CLAYEY SILT, SOME SAND AND GRAVEL WITH COBBLES (GLACIAL TILL)	STIFF TO HARD
			1.8	2.8	DARK GREY SHALE.	WEATHERED
			2.8	8.5	DARK GREY INTERBEDDED SHALE AND LIMESTONE	
MTC 48 PC 316 B.H.#3	CON.1 EHS, LOT 6 CITY OF MISSISSAUGA	191	0.0	1.2	MEDIUM CLAY	HARD
			1.2	1.8	CLAY WITH SHALE FRAGMENTS	VERY HARD

8.4 SUPPORTING CALCULATIONS AND METHODS

In 1856, the French hydraulics engineer Henry Darcy reported that flow through a porous medium is proportional to the head loss and inversely proportional to the distance travelled. The formulation of these relationships is called Darcy's Law and may be written as specific discharge (v) = hydraulic conductivity (K) x gradient (i). The specific discharge is the total discharge per unit area of the discharging porous medium and does not indicate the velocity of the water 'particles'. The velocity of the water (average linear velocity, $\bar{v}$) may be obtained by dividing the specific discharge (v) by the effective porosity (n) of the porous medium. Because effective porosity is always less than 1, the average linear velocity ($\bar{v}$) is always greater than the specific discharge (v).

$$\text{Average Linear Velocity } (\bar{v}) = \frac{\text{hydraulic conductivity (K) x gradient (i)}}{\text{effective porosity (n)}}$$

Once the above parameters are known for a porous medium, an average linear velocity may be calculated. The following example utilizes values typical of lateral flow in the fractured zone:

Lateral Ground Water Flow

- hydraulic conductivity (K) 1×10^{-7} m/s
- lateral gradient (i) 0.008
- effective fracture porosity (n) 0.0001

$$\bar{v} = \frac{ki}{n} = \frac{1 \times 10^{-7} \times 0.015}{0.0001} = 1.5 \times 10^{-5} \text{ m/s or } \approx 500 \text{ m/year.}$$

Vertical Ground Water Flow

The application of Darcy's Law to ground water flow through layered porous media when the layers have differing thicknesses and hydraulic properties is discussed in Freeze and Cherry (1979) and is summarized below with regard to the area under study. The layered porous media of interest are the confining layer subunits which usually include the fractured and unfractured Halton Till, and the lower till. Estimating the rates of ground water flow in each of these layers involves (1) the calculation of a single equivalent hydraulic conductivity for the three layers, (2) calculation of the specific discharge through the layers, and (3) the calculation of average linear velocities in each of the layers.

The calculation of an equivalent hydraulic conductivity (Ke) for the three-layer situation is:

$$Ke = \frac{d(FCL + CL + LT)}{\frac{dFCL}{KFCL} + \frac{dCL}{KCL} + \frac{dLT}{KLT}}$$

where K and d are the hydraulic conductivity and thickness respectively and the subscripts are 'e' (equivalent), 'FCL' (fractured confining layer), 'CL' (confining layer) and 'LT' (lower till).

The calculation of specific discharge (v) uses the equivalent hydraulic conductivity (Ke) and the overall vertical gradient (i) across the layers in Darcy's Law:

$$v = Ki$$

And finally, the average linear ground water velocity ($\bar{v}$) in each layer is obtained by dividing the specific discharge (v) by the effective porosity (n) for each of the layers involved.

The following example uses numbers similar to those in the report (values relate to the layers identified above; thicknesses are in m and hydraulic conductivities are in m/s).

$$Ke = \frac{8.3}{\frac{5.0}{1\times10^{-7}} + \frac{1.7}{1\times10^{-9}} + \frac{1.6}{1\times10^{-8}}} = \frac{8.3}{1.9\times10^{+9}} = 4.4\times10^{-9} \text{ m/s}$$

where the vertical gradient (i) is 0.2

$$v = Kei = 4.4\times10^{-9} \times 0.2 = 8.7\times10^{-10} \text{ m/s}$$
$$\text{or } \approx 2.7\times10^{-2} \text{ m/year.}$$

The average linear velocity ($\bar{v}$) = specific discharge ÷ effective porosity for each individual layer.

For the fractured confining layer, effective porosity (n) = 0.0001 and the average linear velocity ($\bar{v}$) = $8.7 \times 10^{-10}/0.0001 = 8.7 \times 10^{-6}$ m/s or $\approx$300 m/yr.

For the confining layer, no effective porosity value is available and consequently a total porosity value (n) of 0.3 is used to calculate an average linear velocity ($\bar{v}$) = $8.7 \times 10^{-10}/0.3 = 2.9 \times 10^{-9}$ m/s
or $\sim$0.1 m/year.

(These are approximate values and are usually rounded to one significant figure in the text).

The major assumptions for these calculations are:

(1) flow is steady state,
(2) flow is in a direction perpendicular to the layering,
(3) layers are homogeneous and isotropic,
(4) flow is governed by Darcy's Law. A more complete and theoretical discussion is given in Freeze and Cherry (1979).

For a more accurate discussion of ground water flow rates through the confining layer based on advection and diffusion calculations, the reader is referred to Appendix A of the report entitled "Site Slection Process; Phase 4A, Selection of Preferred Site(s), Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

8.5 GLOSSARY OF SELECTED TERMS

Sources are provided at the rear of this section and are referenced by the bracketed number following each definition.

Some definitions are altered slightly to reflect useage in this report and may not reflect the wide range of meanings provided in the source.

8.5 GLOSSARY OF SELECTED TERMS

Alluvium
Sediment composed of organic material, clay, silt, sand, gravel cobbles, or boulders deposited by postglacial streams. (2)

Aquifer
A body of sediment (or rock) that contains sufficient saturated permeable material to conduct ground water and yield economically significant quantities of ground water to wells and springs.(2)

Bearing Pressure (Allowable)
Means the maximum pressure that may be safely applied to a soil or rock by the foundation unit in design under expected loading and subsurface conditions. (8)

Confining Bed (Layer)
A body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers. (1)

Darcy's Law
For the velocity of percolation of water in saturated soil: Velocity = coefficient of permeability x hydraulic gradient. (4) (hydraulic conductivity is used in place of coefficient of permeability in this report).

Desiccated Crust
The exposure of fine-grained sediments to drying is accompanied by shrinkage and possibly cracking. Precompression of the upper portions of clay layers by drying is frequently observed in many of the profiles encountered in practice. The effects of desiccation are an increase in strength and a decreased water content. (6)

Drawdown
The lowering of the water level in a well as a result of withdrawal. (1)

Drift
A general term applied to all rock material (clay, silt, sand, gravel, boulders) transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier. (1)

Evaporite
A nonclastic sedimentary rock composed primarily of minerals produced from a saline solution as a result of extensive or total evaporation of the solvent. Examples include: gypsum, anhydrite, rock salt, primary dolomite, and various nitrates and borates. (3)

Geometric Mean
The nth root of the product of the values of n positive numbers; the antilogarithm of the mean of the logarithms of individual values. (1)

Geotechnical, Geotechnics
Pertaining to the broad field of geotechnics. The application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust for the solution of engineering problems. (1)

Glacial Lake
A lake fed predominantly by glacial meltwater or a lake in a depression in part closed by glacial ice. Includes lakes not directly adjacent to the glacier and lakes lying against or on a glacier, and fed mainly by waters derived from the melting of a glacier. (2)

Glaciofluvial
Pertaining to streams flowing from glaciers or to the deposits made by the streams. (2)

Glaciolacustrine
Pertaining to or characterized by glacial and lacustrine (lake) conditions. Material deposited in lakes affected by glacier ice, or deposited by meltwater flowing directly from glaciers into a lake. (2)

Ground Water
Subsurface water occurring below the water table (phreatic surface) in the saturated zone in which all pores are filled with water under hydrostatic pressure. This contrasts with subsurface water above the water table, which is referred to as soil moisture. (2)

Grout
A cement slurry of high water content, fluid enough to be poured or injected into spaces and thereby fill or seal them. (1)

Hardness (Water)
A property of water causing formation of an insoluble residue when the water is used with soap, and forming a scale in vessels in which water has been allowed to evaporate. It is primarily due to the presence of ions of calcium and magnesium, but also to ions of other alkali metals, other metals (e.g. iron), and even hydrogen. Hardness of water is generally expressed as parts per million as $CaCO_3$ (40 ppm Ca produces a hardness of 100 ppm as $CaCO_3$); also as milligrams per litre, and is the combination of carbonate hardness and noncarbonate hardness. (1)

Hazardous Waste
Waste that poses a present or potential danger to human beings or other organisms because it is toxic, flammable, radioactive, explosive, or has some other property that produces substantial risk to life. (1) (Use here excludes radioactive waste)

Heave
A predominantly upward movement of a surface, caused by expansion or displacement, as from swelling clay, removal of overburden, seepage pressure, or frost action. (1)

Hydraulic Gradient
In an aquifer, the rate of change of total head per unit of distance of flow at a given point and in a given direction. (1)

Hydraulic Head
The height of the free surface of a body of water above a given subsurface point. (1)

Hydraulic conductivity
The proportionality factor in Darcy's law as applied to the viscous flow of water in soil, that is, the flux of water per unit gradient of hydraulic potential. (3)

Hydrogeology
The science that deals with subsurface waters and with related geologic aspects of surface waters. (1)

Hydrostratigraphic Unit
A term proposed by Maxey (1964, p. 126) for a body of rock having considerable lateral extent and composing "a geologic framework for a reasonably distinct hydrologic system". (1) (used here for soil and rock).

Infiltration
The flow of a fluid into a solid substance through pores or small openings; specifically the movement of water into soil or porous rock. (1)

Lamina
The thinnest recognizable unit layer of original deposition in a sediment or sedimentary rock, differing from other layers in colour, composition, or particle size; specifically such a sedimentary layer less than 1 cm in thickness (commonly 0.05-1.00 mm thick). (1)

Log
A continuous record as a function of depth, usually graphic and plotted to scale on a narrow paper strip, of observations made on the rocks and fluids of the geologic section exposed in a well bore. (1) (used here for soil and rock).

Moraine
Accumulation of glacial material (mainly till) deposited by glaciers. (2)

Particle Size Classification System (9)

Name	Qualifying Term	Approximate Particle Size (mm)
Boulders		>200
Cobbles		60-200
Gravel	(Pebble)	2-60
Sand	Coarse	0.6-2
	Medium	0.2-0.6
	Fine	0.06-0.2
Silt		0.002-0.06
Clay		<0.002

Permeability
The capacity of a porous medium to transmit a liquid or gas subjected to an energy gradient (in the case of water, hydraulic gradient). (2)

Porosity
The ratio of the volume of voids to the total volume of a soil sample. (4). Effective porosity is the amount of interconnected space available for fluid transmission (3).

Quaternary
The youngest period of the two geologic time divisions of the Cenozoic Era. The Quaternary is subdivided into the Pleistocene and Recent (or Holocene) Epochs. It comprises all geologic time and deposits from the end of the Tertiary (approximately 2 million years ago) until and including the present. (2)

Saturated
Said of the condition in which the interstices of a material are filled with a liquid, usually water. It applies whether the liquid is under greater than or less than atmospheric pressure, so long as all connected interstices are full. (1)

Settlement
Downward movement of a structure such as a railway bridge, dam, or building, due to compression or movement of the soil below it. (4)

Shear Strength
The internal resistance offered to shear stress. It is measured by the maximum shear stress, based on original area of cross-section, that can be sustained without failure. (5)

Two extreme conditions may be recognized: drained conditions, under which the changes in stress are applied so slowly with respect to the ability of the soil to drain that no excess pore pressures develop, and undrained conditions, under which the stresses are changed so rapidly with respect to the ability of the soil to drain that no dissipation of pore pressure takes place. (7)

Slug Test
A method of determining in situ hydraulic conductivity in a single piezometer by causing an instantaneous change in the water level by adding or displacing a known volume of water. (10)

Split Spoon Sampler
Sampling spoons for exploratory borings commonly consist of a pipe with an inside diameter of about 35 mm and an outside diameter of about 51 mm. The pipe is split lengthwise. Consequently the sampler is called a split spoon. While the sample is being taken, the two halves of the spoon are held togther at the ends by short pieces of threaded pipe. One piece serves to couple the spoon to the wash pipe. The other, which has been sharpened, serves as the cutting edge while the spoon is driven into the soil. Exact dimensions are designated in ASTM DI586-67. (7)

Static (Water) Level
That water level of a well that is not being affected by withdrawal of ground water. (1)

Stratigraphic Unit
A stratum or body of adjacent strata recognized as a unit in the classification of a rock sequence with respect to any of the many characters, properties, or attributes that rocks may possess. (1)

Surcharge Load
A weight per unit of area of fill great enough to consolidate the soil sufficiently to increase its strength or reduce its compressibility to the required extent within the time available. Compressible soils such as clays, loose silts, and most organic soils may be compacted by surcharging. (7)

Till
An unsorted mixture of clay, silt, sand, pebbles, cobbles and boulders deposited directly by glacier ice. (2)

Water Table
A surface in the saturated zone below ground level along which the hydrostatic pressure is in equilibrium with the atmospheric pressure. (2)

Weathering
The destructive process or group of processes by which earthy and rocky materials on exposure to atmospheric agents at or near the earth's surface are changed in colour, texture, composition, firmness, or form with little or no transport of the loosened or altered material; specifically, the physical desintegration and chemical decomposition of rock that produce an in situ mantle of waste and prepare sediments for transportion. (1)

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8.6 DETAILED FIELD METHODS

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8.6.1 INTRODUCTION

Field data for of the Phase 4A hydrogeologic onsite investigations were collected in a standardized fashion and formed part of the basis for geologic, hydrogeologic, and geotechnical comparisons of the eight candidate sites. An outline of the major field activities is shown in Figure 9. The study approach was modified only slightly on a site-by-site basis to accommodate differing circumstances and site conditions. Standard procedures for the drilling and sampling operations, as outlined in the Gartner Lee Associates Ltd. "Drilling and Sampling Protocol" document (GLAL 1984a), were adhered to throughout the drilling program. This protocol document provides examples of field forms used to document field activities and should be referred to for more detailed drilling and sampling procedural descriptions.

8.6.2 DRILL SITE IDENTIFICATION

8.6.2.1 Preliminary data analysis

A preliminary review of existing water well and test hole data was completed to establish a basis for the selection of tentative drill locations. Criteria used included the following:

- the distribution of existing test holes and water wells;
- the continuity of existing data; and
- anomalous or unusual site conditions.

While locations were selected primarily on technical grounds, practical considerations such as site access, potential crop damage, and landownership were also taken into account.

DETAILED FIELD METHODS

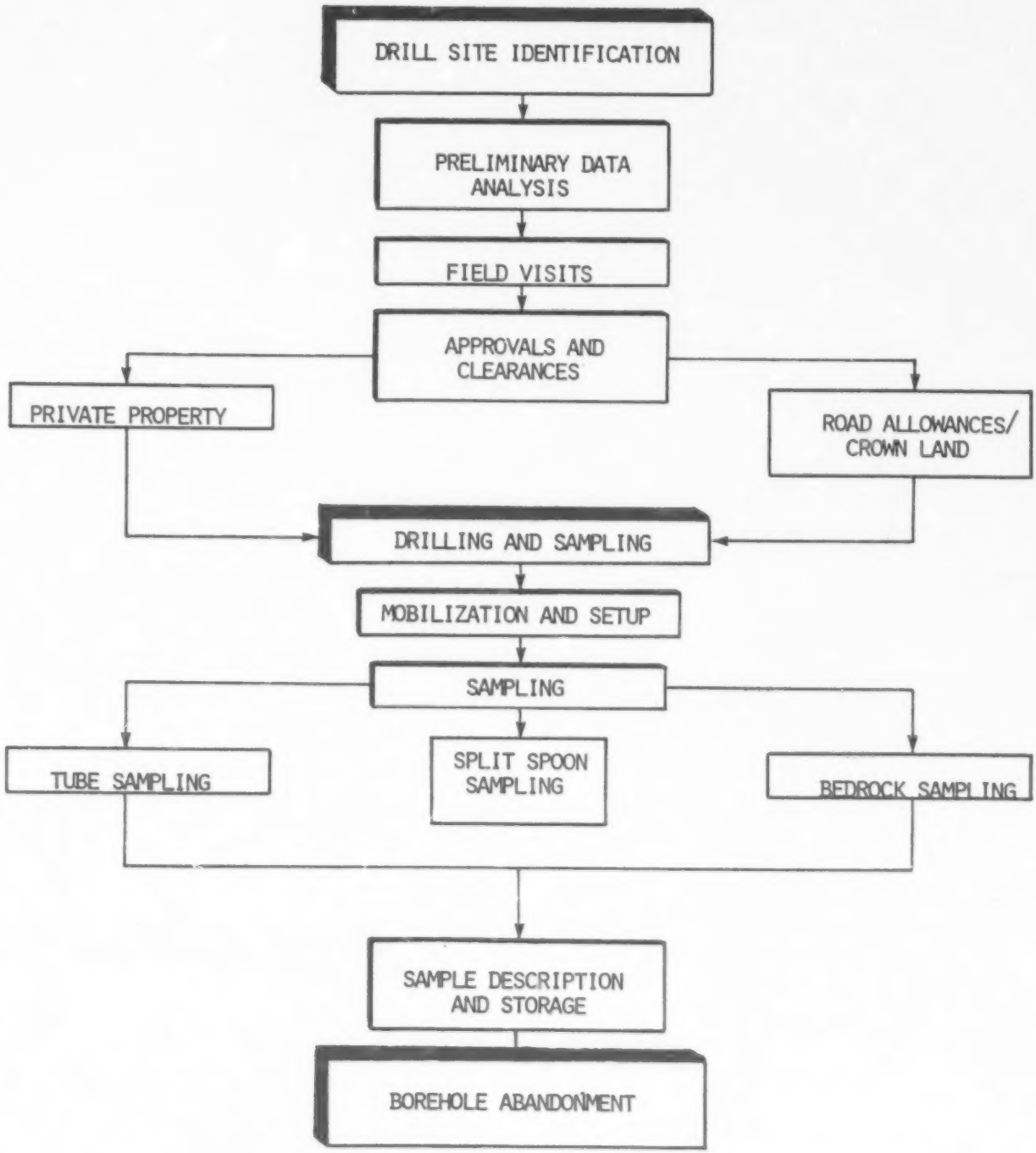

Figure 9

8.6.2.2 Field visits

The concerns of local public interest groups and individuals were also considered in selecting drill locations. Local interest groups were invited to participate during field checking of the drill locations. During these field visits, additional data on water use, local soil conditions, and wells were obtained from local residents. This information was used as a check on some of the field data obtained previously by Ecolgistics Limited during the 1984 "Walk and Talk" survey. The amount of information thus obtained varied from site-to-site and depended largely upon the degree of co-operation given by residents and landowners.

A limited amount of soil probing was completed at Candidate Sites LF-3C, LF-9C, and PI-13N using a 25 mm (1 inch) magnesium hand auger. These investigations were generally limited to a depth of 1 to 2 m. Hand augering was directed toward areas of suspected granular soils or anomalous soil conditions identified by local residents. Soil probing was confined to areas where property access was permitted. Soil descriptions are included under "Field Station Descriptions" in the individual technical site reports.

The tentative drill locations were adjusted during the field visits to avoid difficult or unsafe drilling locations. Each location was marked with a temporary wooden stake. Final adjustments were subsequently made, where necessary, to provide the required safe setbacks from buried and overhead services.

8.6.2.3 Approvals and Clearances

Clearances for both road allowances and adjacent private

or public property were pursued where identified drilling locations were located in the vicinity of local roads. Road allowances were drilled where access to private property was denied.

Landowners and tenants of affected properties were initially contacted by GLAL and verbal approval for test drilling was obtained. Approval was confirmed with a follow up letter from OWMC. For road allowance clearances, the appropriate agencies were contacted and the necessary permit approvals were obtained.

Utilities were contacted and buried service cables and/or pipes were field located by utility personnel and final adjustments of drill locations were completed. Drilling approvals and clearances were completed on a site-by-site basis.

8.6.3 DRILLING AND SAMPLING

8.6.3.1 Drilling equipment and setup

All Terrain Drilling Limited was retained to provide drilling services. The drilling equipment included truck and track mounted CME 75 auger drilling rigs. Two rigs were used simultaneously for most of the drilling program. Each rig was equipped to drill and sample both soils and bedrock. Each rig was staffed with a three man drilling crew and supervised by a GLAL geologist. The drilling program was initiated on August 13, 1984 at Site LF-3C and was completed on November 22, 1984 at Site LF-4N.

The drill rigs were set up in accordance with standard drilling practices and in a manner that allowed the safe

and efficient operation of the equipment. A safety corridor was roped-off around the drill rig to limit access to the rigs. Access to the roped-off area was restricted to individuals with proper safety equipment which included steel-toed boots and a hard hat. A record was kept of all visitors to the drill site as well as persons entering the roped-off area.

Sample documentation and storage facilities were set up at the edge of the roped-off area by GLAL. Soil and rock samples were accessible to the general public for viewing and/or photographing as the samples were being logged by the onsite geologists. Samples were subsequently sealed in tubes or core boxes, labelled, and placed in storage. On several occasions, soil sample tubes were re-opened for examination at the request of local residents.

8.6.3.2 Soil sampling

The drilling program was designed to obtain a continuous column of soil from the ground surface to and including the upper few metres of the underlying bedrock. Soil samples were obtained using hollow stem auger drilling techniques. Hollow stem augers (108 mm (4.25 inch) inside diameter) were used throughout the drilling program.

Split tube sampling. Tube samples measuring approximately 89 mm (3.5 inches) in diameter by 1.52 m (5 ft.) in length were taken continuously from ground level to the bedrock surface. The tube sampler consisted of a split tube with a bevelled sampler tip. The split tube was threaded at both ends and fastened to the drill rods as shown in Figure 10. The sampler as advanced inside the hollow stem augers with

Continuous Soil Sampling With Split Tube Sampler

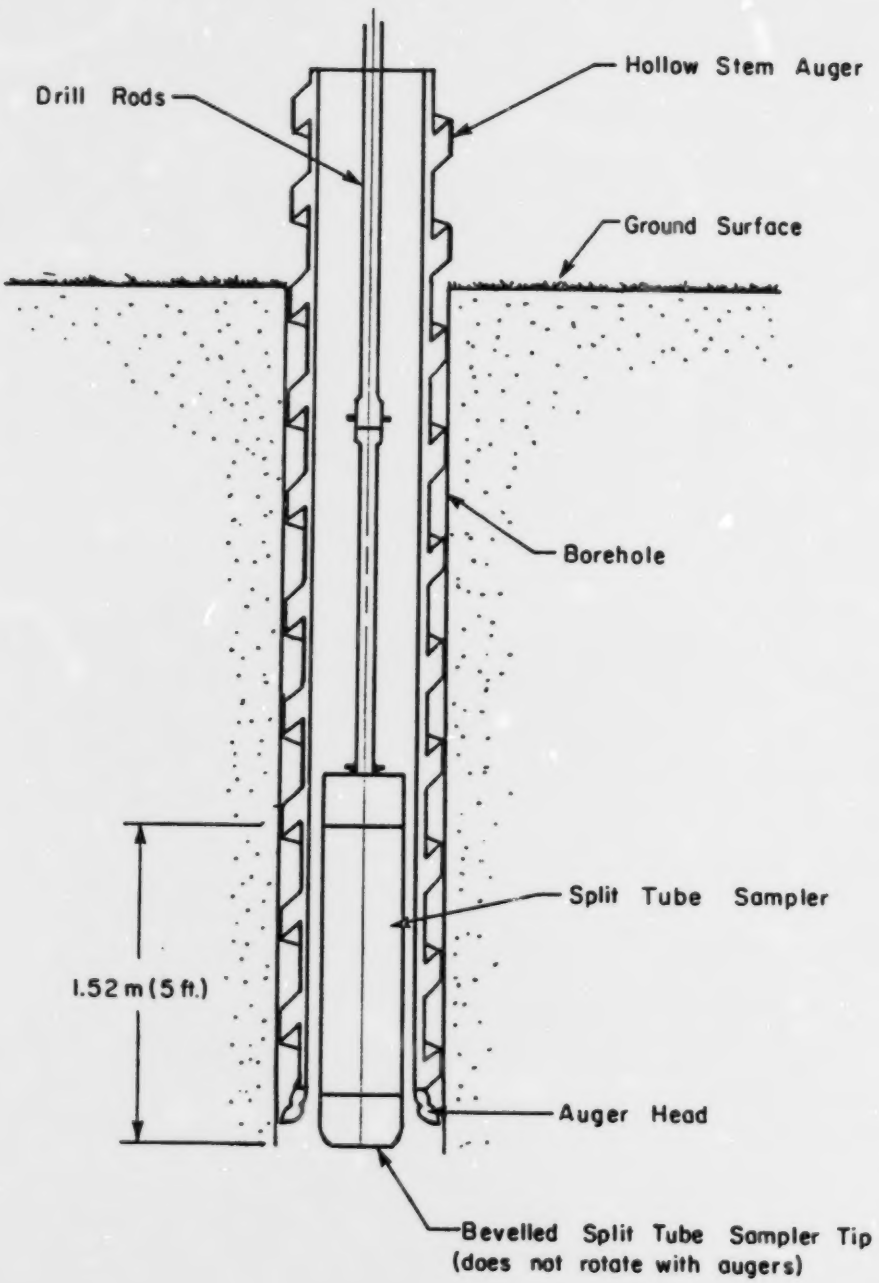

Figure 10

the bevelled tip slightly ahead of the cutting edge of the augers. A split tube sample was obtained by advancing the sampler with the rotating augers. The augers and sampler were advanced at about 1.52 m (5 ft.) intervals or until refusal, and the sampler was then withdrawn from the borehole. The soil sample was removed from the tube and the sampler washed with clean water. Sample recovery for the tube samples was generally between 90 to 100% and was recorded in the field log. Difficult drilling conditions or large cobbles occasionally resulted in lower sample recovery.

Split spoon sampling. Standard split spoon samples were taken at about 1.52 m (5 ft.) intervals throughout the soil sequence overlying bedrock and beginning at about 1.52 m 5 ft.) from the ground surface. Sample intervals are shown schematically in Figure 11.

The split spoon sampler was driven by dropping a 63.5 kg (140 lb.) weight a distance of about 750 mm (30 inches). The sampler was inserted inside the hollow stem augers in a similar fashion to the tube sampler. It was then driven into the soil below the bottom of the augers a distance of about 460 mm (18 inches) or until refusal. The number of blows required to advance the sample for each interval of about 150 mm (6 inches) was recorded in the field log. The split spoon was usually withdrawn when 50 or more blows were required to advance the sampler approximately 150 mm (6 inches) into the subsoil.

Standard split spoon samples were obtained in place of tube samples where difficult drilling conditions were

Soil & Rock Sample Intervals Phase 4A Drilling Program

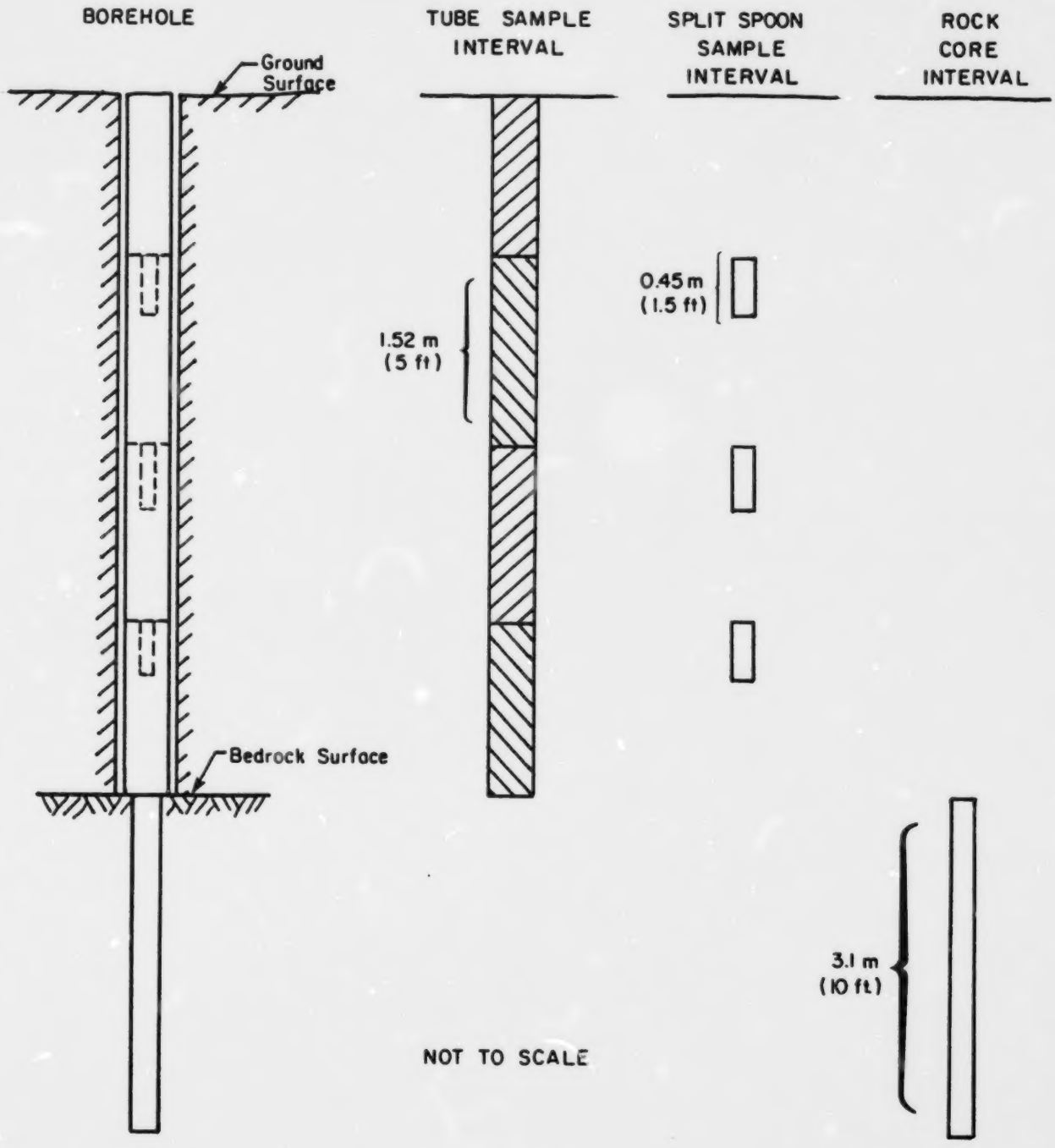

Figure 11

encountered. At Site LF-4N, Borehole 4, granular soils were encountered at a depth of about 30 m (100 ft.) causing refusal of the tube sampler. Standard split spoon samples were taken from a depth of 30 m (100 ft.) at intervals of 0.5 to 3 m (1.6 to 9.8 ft.) to a depth of about 40 m (130 ft.). Difficult soil conditions were also encountered at Site LF-2N, Borehole 1. Numerous rock fragments were encountered below a depth of about 12 m (40 ft.) at this location. Split spoon samples at 0.76 m (2.5 ft.) intervals were taken between depths of about 12 m (40 ft.) to 34 m (110 ft.).

Difficult (sandy and gravelly) soil conditions at Site PI-27E, Borehole 3 prevented tube sampling between depths of about 16 to 30 m (50 to 100 ft.). Similar fine, sandy soils were also encountered in Borehole 4 at this site at depths between approximately 24 to 30 m (80 to 100 ft.). Standard split spoon samples at 1.5 m (5 ft.) intervals were collected over these intervals at these two borehole locations.

Moisture tin samples. A small soil sample of approximately 100 grams was taken from the tip of each split spoon sample for laboratory determination of the soil moisture content. Soil moisture samples were placed in air tight tins immediately after they were taken from the split spoon samples. The moisture tin (sample) numbers were recorded on the field borehole logs. The samples were temporarily stored in the field and shipped in batches to the GLAL office for transfer to a commercial laboratory.

Rotary drilling. Rotary drilling techniques were occas-

ionally used to penetrate difficult soils that could not readily be drilled with conventional hollow stem auger drilling methods. These techniques were also used where granular soils, acting under hydraulic pressures, were forced up inside the hollow stem augers. This condition prevented the split tube and split spoon samplers from passing through the plugged portions of the hollow stem augers. Clean water or a water/bentonite mixture was circulated through a rotating tricone drill bit to clean out the material in the hollow stem augers. Rotary drilling was also used to drill through gravelly or bouldery soils such as those encountered at depth at Site LF-4N, Borehole 4, and at Site LF-2N, Borehole 1.

8.6.3.3 Bedrock sampling

Boreholes were generally completed into bedrock except in a few cases where difficult drilling conditions were encountered and the borehole was terminated before reaching bedrock.

The bedrock contact was often obscured as a result of weathering, particularly in shale. Under conditions of extreme weathering, shale was occasionally retrieved within the split tube and split spoon samplers. For example, a nearly complete 1.5 m core of weathered bedrock was obtained in the split tube sampler in Borehole 5 at Site PI-13N.

Diamond drill coring. Most bedrock samples were obtained using a diamond drill bit and NX size core barrel. Rock core samples generally measured about 53 mm (2.1 inches) in diameter and up to 3 m (10 ft.) in length. The diamond drill bit and core barrel were positioned on the bedrock

surface from inside the hollow stem augers. A rock core was obtained by the cutting action of the rotating drill bit. Clean water was circulated in the borehole to remove cuttings from around the drill bit. The water used in this operation was field checked with a Hach Kit for chlorides and sulphates to ensure compatibility with grouting materials used for borehole abandonment. The amount of water used was recorded on the field logs.

Bedrock coring was terminated when a sufficient length of sample was retrieved to prove-out the bedrock contact. The bedrock core recovered varied in length from about 1.5 m to 3 m (5-10 ft.) between borehole locations.

8.6.3.4 Sample description and storage

Soil and rock samples, taken from the boreholes, were described in detail in the field and photographed. Sample descriptions were recorded on the Field Borehole Log forms. These logs, together with the sample photos, form a permanent record of the sampling procedures.

The tube samples were transferred directly from the sampler into PVC tubular piping which was cut in half. The PVC pipe measures 89 mm (3.5 in.) inside diameter by 1.5 m (5 ft.) long. One 'side' of the sample was scraped clean along its length with a knife or spatula to facilitate sample description. Individuals and local interest groups were allowed to view the samples and make their own field notes of the samples. Soil scrapings were given to those interest groups that requested them or else were discarded. Soil samples were sealed in the PVC tubes by covering the

ends with plastic caps and taping the entire tube along the seams. Sample labels were affixed to each PVC tube.

The samples were stored temporarily in a field van until a sufficient number of samples were obtained for transport to permanent storage facilities in Toronto at the Ontario Geological Survey. Each shipment of samples were itemized on a Sample Packing list. The contents of each shipment were also recorded on a Chain of Custody Record which showed the times and dates of sample transfer as well as the individuals involved in handling the samples.

Split spoon soil samples taken during the project were described in the field and soil moisture (moisture tin) samples taken from the base of the split spoon sampler were submitted to a laboratory for analysis. The moisture tin number was recorded on the Field Borehole Log and on the Sample Packing List. In cases where a split spoon sample was taken in place of the larger split tube samples, they were stored in labelled plastic bags and retained with the other samples. The top of each bedrock core segment was marked on both the core boxes and on the rock core itself with a felt marker.

The soil and rock samples were re-examined by a senior GLAL geologist at the permanent storage area at the Ontario Geological Survey. The field descriptions were combined with the more detailed geologic log prepared by the senior geologist to compile a final borehole log. All soil samples were resealed after examination.

8.6.4 BOREHOLE ABANDONMENT

Boreholes were generally terminated after pentrating the bedrock or when difficult conditions prevented further drilling. An exception to this occurred at Site LF-1E, Borehole 3, where a gas pocket was encountered at a depth of about 17.8 m (58 ft.) in the drift. The borehole was terminated at this depth and sealed as soon as the gas pressure subsided sufficiently to allow grouting.

8.6.4.1 Grouting

On completion of each borehole all sampling equipment and temporary casing were removed from the borehole. Each borehole was then filled to the surface with a cement/ bentonite slurry. This was accomplished by injecting grout through the hollow stem augers as they were slowly withdrawn from the hole as shown in Figure 12. Specifications of the slurry mix, as set out in the Drilling and Sampling Protocol Document (GLAL 1984a) were altered slightly to accommodate site conditions. The actual grout slurry mix is compared on a percent weight basis to the specified grout slurry mix below:

Specified Grout Slurry	Actual Grout Slurry
1.2% Bentonite	2-3% Bentonite
6.0% Hydrated Lime (optional)	
59.6% Cement (Portland Type 10)	40-60% Cement (Portland Type 10)
33.2% Water	37-58% Water

The increased amount of bentonite provides a more effective seal in water bearing formations. The bentonite also acts as a 'plasticizing' agent and eliminated the need

Grouting Of Borehole

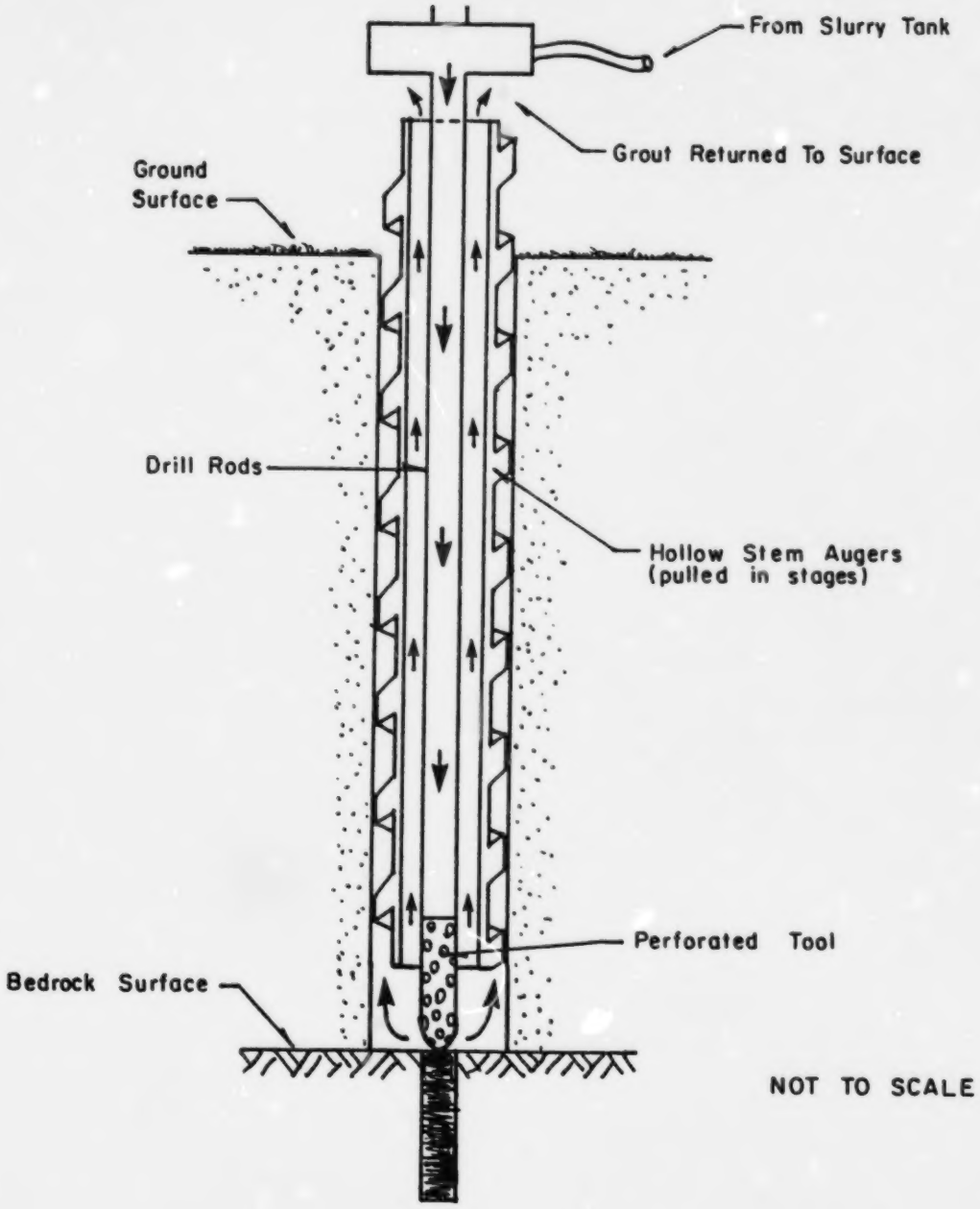

Figure 12

to add hydrated lime to the grout slurry mix. A cement mix containing slightly less than the amount of cement specified in the protocol was found to be adequate. A small sample of grout slurry was taken from each hole to confirm the setting characteristics of the mix.

The water used in the grout slurry was obtained locally and was tested wth a Hach Kit for sulphate and chloride content. Details of each grout mix were recorded on the Borehole Plugging Plan/Record for each borehole.

The grout was allowed to set overnight and generally settled to within 1 to 3 m (3-10 ft.) of ground surface. The hole was subsequently backfilled to grade with soil to avoid interference with surface activities such as ploughing or maintenance along road allowances. All boreholes from this drilling program were successfully grouted.

8.6.4.2 Site cleanup

Efforts were made to restore each drill location to predrilling conditions. The ground was levelled to grade and holes or ruts made by drilling equipment were filled with soil and in some cases resodded. While attempts were made to minimize damage, this was not always possible and compensation was provided in some cases. Photographs were taken of each drill location both before and after the drilling operations and after site cleanup.

STEELES AVENUE
PEEL VILLAGE
HIGHWAY 410
ETOBICOKE CREEK
SECOND LINE EAST
CITY of MISSISSAUGA
MOUNT CHARLES
DERRY ROAD EAST
DIXIE ROAD
PEARSON INTERNATIONA
COURTNEY PARK AVENUE
FIRST LINE EAST
LOT 13 CON 2E
LOT 12 CON 1E
LOT 15 CON 1W
LOT 14 CON 1E
LOT 10 CON 3E
LOT 11 CON 3E
HURONTARIO STREET
FIRST LINE WEST
A
B
MTC 32 (189)
MTC 33 (190)
MTC 28 (195)
MTC 26 (191)
MTC 31 (185)
GL 2 (194)
MTC 27 (206)
2511 (208)
2512 (208)
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2513 (205)
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1908 (205)
2345 (206)
2340 (201)
2343 (201)
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3594 (202)
GL 5 (203)
2508 (205)
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OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

GL 3	GARTNER LEE ASSOCIATES LIMITED BOREHOLE NO. 3
MTC 47	MINISTRY OF TRANSPORTATION AND COMMUNICATIONS BOREHOLE NO. 47
2338 (200)	WATER WELL LOCATION WITH ONTARIO MINISTRY OF THE ENVIRONMENT WELL NO. ESTIMATED SURFACE ELEVATION IN METRES ABOVE SEA LEVEL (IN BRACKETS)
A — A'	CROSS-SECTION

Phase 3B Acquisition Boundary

Site Vicinity Study Area Boundary

Key Map: **LF-2 North**

Lots 9 and 10; Concession I EHS (East of Hurontario Street), City of Mississauga

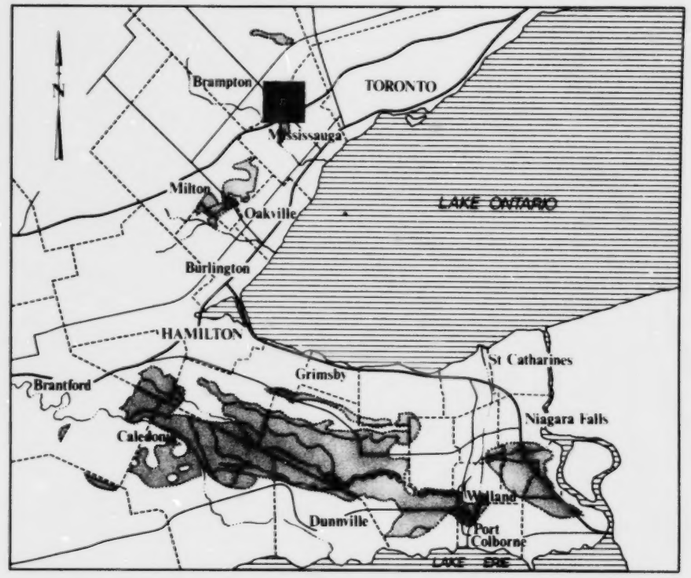
FIRST LINE WEST
SECOND LINE WEST
DERRY ROAD
MEADOWVALE VILLAGE
FLETCHERS CREEK
LOT 9 CON 2W
LOT 11 CON 3W
CREDIT RIVER
HIGHWAY 401
MACDONALD CARTIER FREEWAY
LOT 9 CON IW
LOT 6 CON 2W
BRITANNIA ROAD
McLAUGHLIN ROAD
HIGHWAY 10
LOT 5 CON IW
LOT 4 CON IE
BRITANNIA
MISSISSAUG
GLEN ERIN DRIVE
CP
A
B
Contour Interval
1:10 000 base mapping
Ministry of Natural Res

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map:

LF-2 North

Lots 9 and 10; Concession I EHS (East of Hurontario Street), City of Mississauga



1000 feet 0 1000
500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Well and Borehole Locations

September 1985

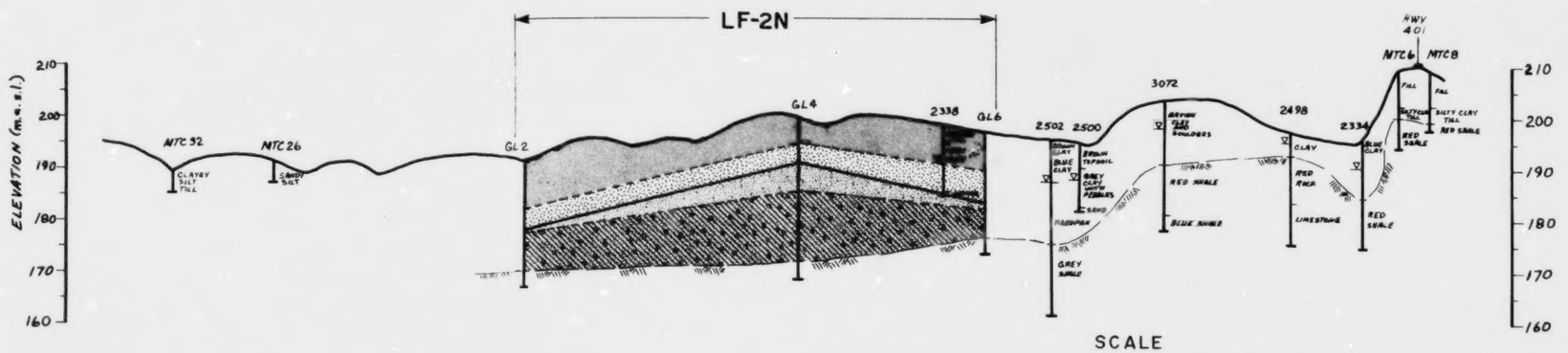
FIGURE 4

Contour Interval in Metres

1:10000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

North — Looking West — South

A — A´



(Geologic conditions between boreholes may vary from interpretations shown)

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

Site LF-2N
CROSS-SECTION A–A´
Figure 5

LEGEND

GL 3 — Gartner Lee Associates Limited (GLAL) Borehole
417 — Ministry of Environment Water Well Record Number
▽ — Static Water Level in Well at Time of Well Construction
m a s l — Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- SILT TILL (Halton Till)
- SILTY SAND TO SANDY SILT TILL (Lower Till)
- SAND
- INTERBEDDED SILT TILLS AND SAND (Lower Till & Sand)
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

NOTES - Consult Water Well Record Summary and Borehole Logs in Sections B.1 and B.3 for detailed descriptions.

Elevations are approximate
Cross Section Located in Figure 4.

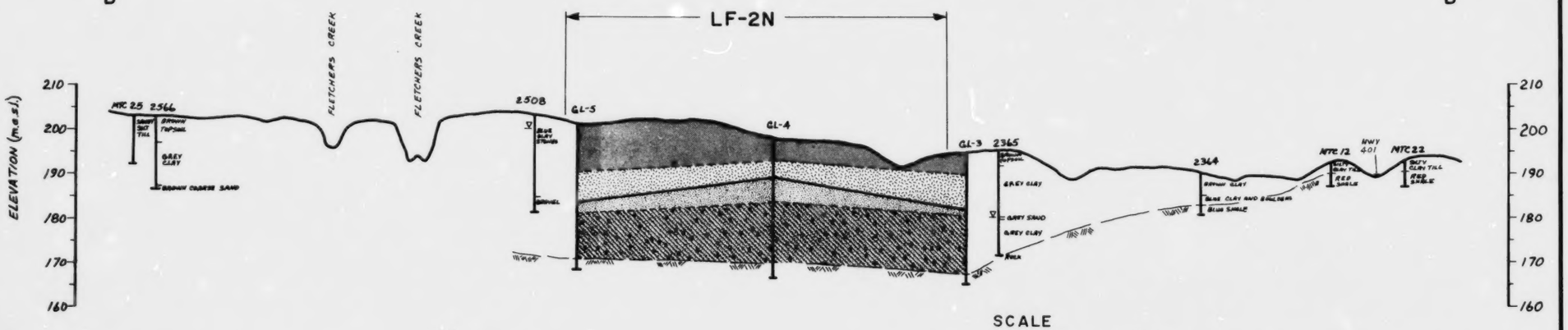
To accompany Phase 4A Technical Appendix (Geologic Hydrogeologic and Geotechnical Considerations)

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

West — Looking North — East

B — B´



(Geologic conditions between boreholes may vary from interpretations shown)

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

Site LF-2N
CROSS-SECTION B–B´
Figure 6

LEGEND

GL 3 — Gartner Lee Associates Limited (GLAL) Borehole
417 — Ministry of Environment Water Well Record Number
▽ — Static Water Level in Well at Time of Well Construction
m a s l — Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- SILT TILL (Halton Till)
- SILTY SAND TO SANDY SILT TILL (Lower Till)
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- INTERBEDDED SILT TILLS AND SAND (Lower Till & Sand)
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

NOTES - Consult Water Well Record Summary and Borehole Logs in Sections B.1 and B.3 for detailed descriptions.

Elevations are approximate
Cross Section Located in Figure 4.

To accompany Phase 4A Technical Appendix (Geologic Hydrogeologic and Geotechnical Considerations)

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

PEEL VILLAGE

STEELES AVENUE

HIGHWAY 410

ETOBICOKE CREEK

MOUNT CHARLES

SECOND LINE EAST

DIXIE ROAD

DERRY ROAD EAST

PEARSON INTERNATIONA

COURTNEY PARK DRIVE

FIRST LINE EAST

LOT 13 CON 2E

LOT 14 CON 1E

LOT 15 CON 1W

LOT 12 CON 2E

LOT 11 CON 2E

LOT 10 CON 3E

LOT 12 CON 1E

HURONTARIO STREET

FIRST LINE WEST

MTC 32 7.5†

MTC 28 3.5†

MTC 26 8.2†

MTC 30 9.3†

2344 10.4

2345 8.2

GL 2 15.5

MTC 39 1.4

MTC 34 13.7

GL 1 8.3

2343

2359 16.8

2408 12.8

2345 16.8

MTC 29 12.3†

2342

3594 22.9

GL 3 13.0

2365 15.2

GL 4 8.8

MTC 25 10.9†

2366 15.8

2304 21.9

2364 7.3

MTC 12 2.7

2512 19.3

2514 19.3

2513 22.6

2344 12.2

2336 10.4

GL 6 13.6

2337

2501 9.8

2502 12.8

2504 7.4

2507 12.7

2510 11.3

5539 7.0

4910 6.4

2506 7.6

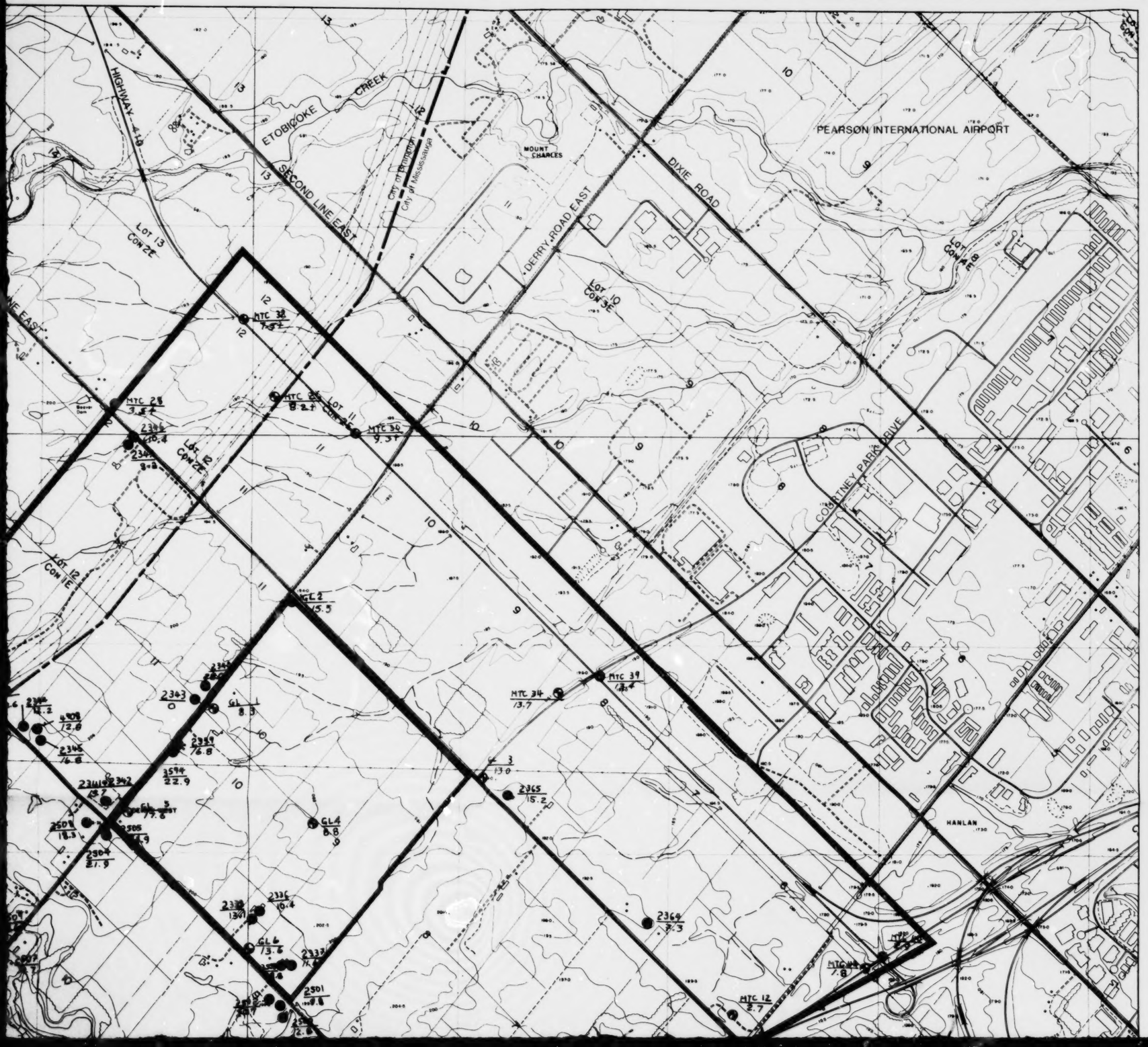
2509 14.2

2505 17.9

2503 18.3

2341

MTC 38 1.8



OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

- GL 3 — GARTNER LEE ASSOCIATES LIMITED BOREHOLE
- MTC — MINISTRY OF TRANSPORTATION AND COMMUNICATIONS BOREHOLE
- 2504 — WATER WELL WITH MINISTRY OF THE ENVIRONMENT WELL No.
- 14 — THICKNESS OF CONFINING LAYER (METERS)

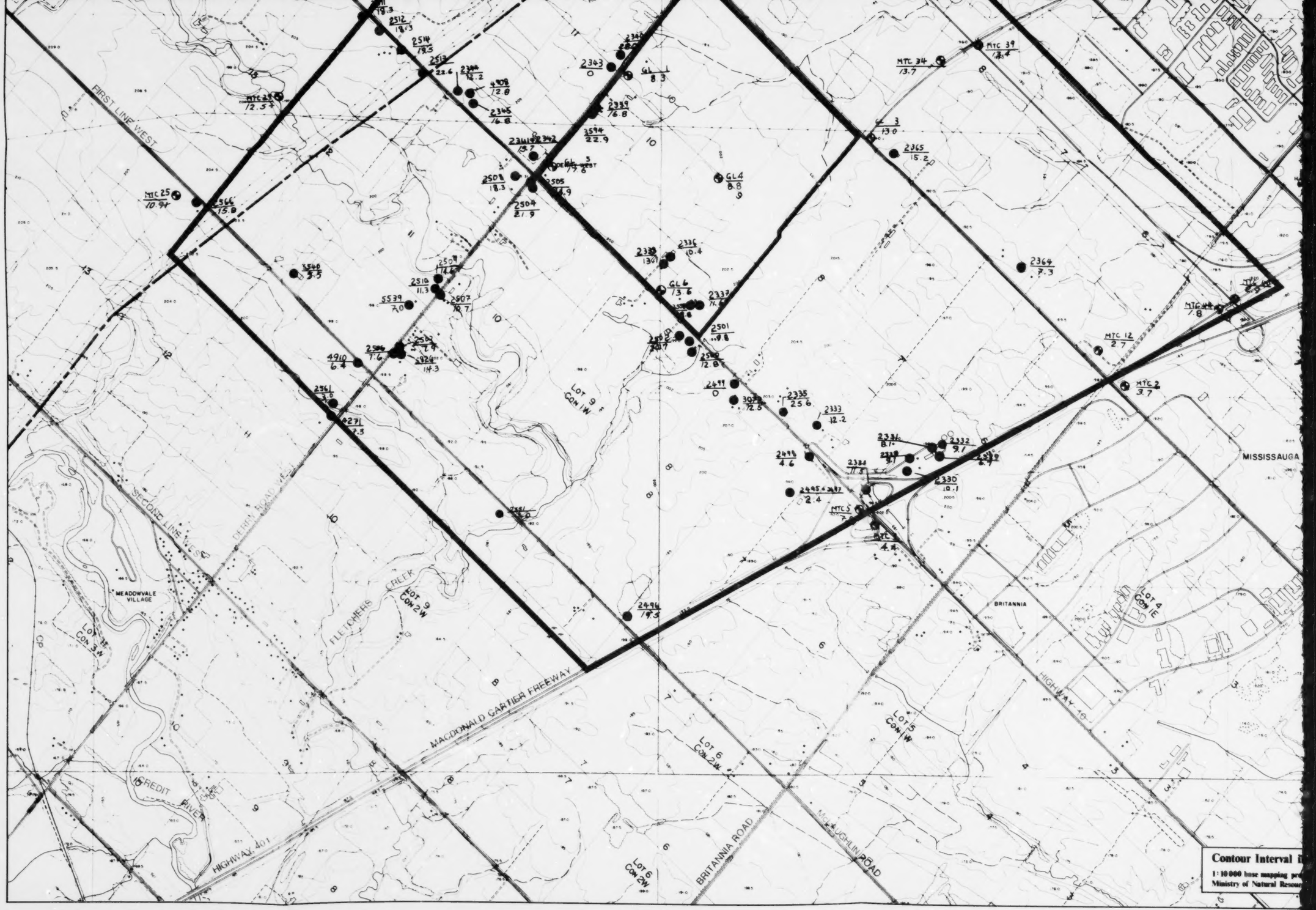
Phase 3B Acquisition Boundary

Site Vicinity Study Area Boundary

Key Map:

LF-2 North

Lots 9 and 10; Concession I EHS (East of Hurontario Street), City of Mississauga

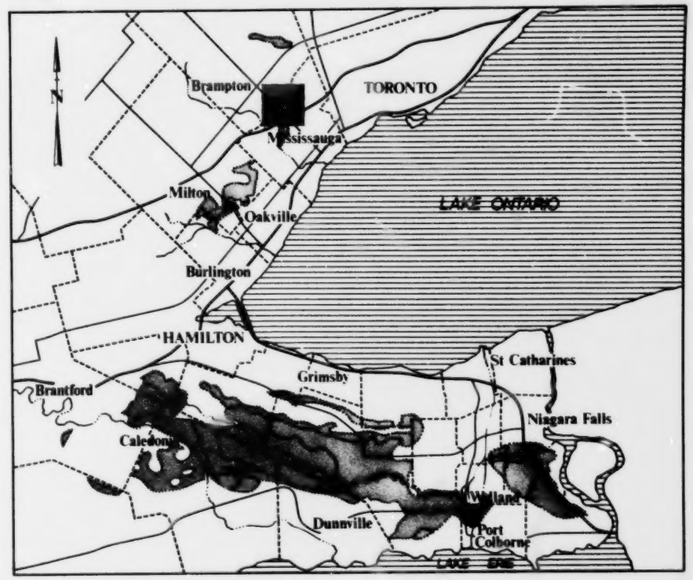

FIRST LINE WEST
SECOND LINE WEST
DERRY ROAD W
MTC 25
10.9
2366
15.8
3546
3.5
2509
14.6
2510
11.3
5539
7.0
2507
12.7
2504
21.9
2501
18.3
2505
4.9
2512
18.3
2514
19.5
2513
22.6
2345
16.8
2343
0
GL1
8.3
2339
16.8
3594
22.9
GL4
8.8
2365
15.2
MTC 34
13.7
MTC 39
14.4
2364
7.3
2336
10.4
GL6
13.6
2501
9.8
2499
0
2335
25.6
2333
12.2
2332
9.1
2330
10.1
2498
4.6
2495+2497
2.4
MTC 5
4.4
MTC 12
2.7
MTC 2
3.7
MTC 44
1.8
MISSISSAUGA
BRITANNIA
LOT 9 CON 1W
LOT 9 CON 2W
LOT 6 CON 2W
LOT 5 CON 1W
LOT 4 CON 1E
LOT 11 CON 3W
MEADOWVALE VILLAGE
FLETCHERS CREEK
MACDONALD CARTIER FREEWAY
HIGHWAY 401
HIGHWAY 10
CREDIT RIVER
BRITANNIA ROAD
McLAUGHLIN ROAD
CP
4910
6.4
2524
14.3
2271
7.3
2496
19.5
Contour Interval
1:10 000 base mapping
Ministry of Natural

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map:

LF-2 North

Lots 9 and 10; Concession I EHS (East of Hurontario Street), City of Mississauga



1000 feet 0 1000

500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

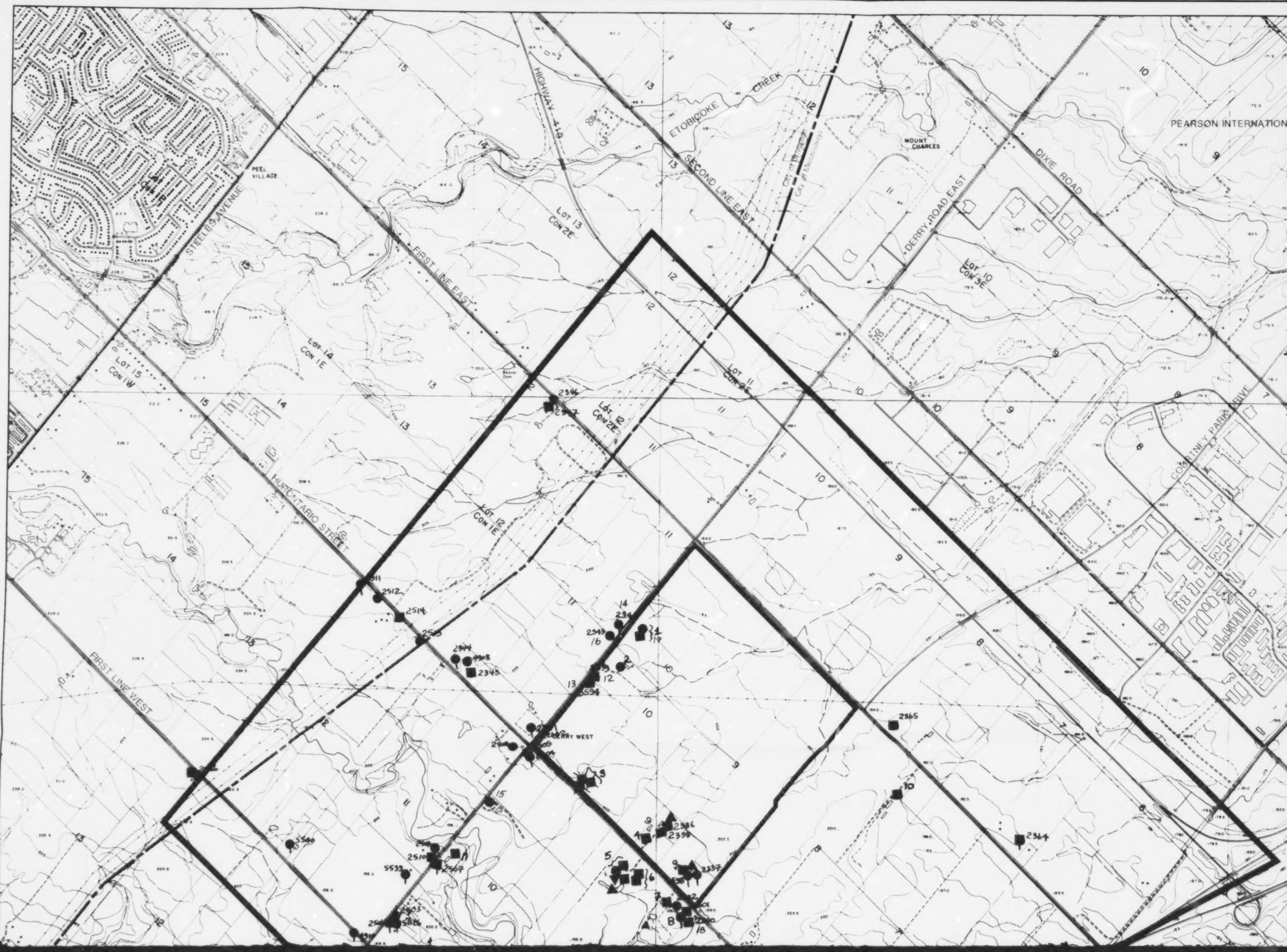
Confining Layer Thickness

September 1985

FIGURE 7

Contour Interval in Metres

1:10000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984


PEEL VILLAGE
STEELES AVENUE
HIGHWAY 410
ETOBICOKE CREEK
SECOND LINE EAST
MOUNT CHARLES
DIXIE ROAD
PEARSON INTERNATION
DERRY ROAD EAST
FIRST LINE EAST
Lot 13 Con 2E
Lot 14 Con 1E
Lot 15 Con 1W
Lot 12 Con 2E
Lot 11 Con 2E
Lot 10 Con 3E
HURONTARIO STREET
Lot 12 Con 1E
FIRST LINE WEST
COURTNEY PARK DRIVE
DERRY WEST

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

- ●, ● DRILLED WELL COMPLETED IN OVERBURDEN, BEDROCK
- ■, ■ DUG OR BORED WELL COMPLETED IN OVERBURDEN, BEDROCK
- /, × UNUSED, ABANDONED WELL
- ▲ DUGOUT OR POND
- ▼ CISTERN

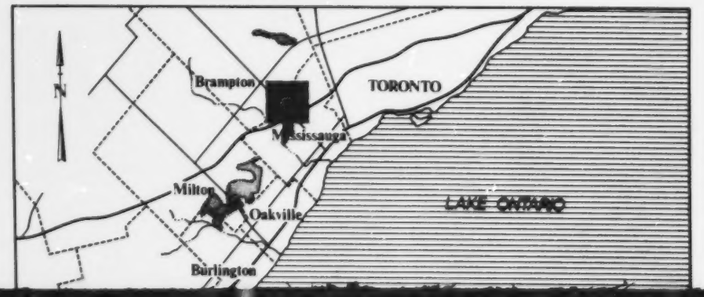
Details for wells with Ministry of Environment numbers (4 digits) are provided in the Summary of Water Well Data (Table 4, Section 8.1); Other numbers accompany wells, cisterns, dugouts or ponds, and locations where 'additional field information' was gathered. Details for these are provided in the Summary of Site Interview Data (Table 5, Section 8.2)

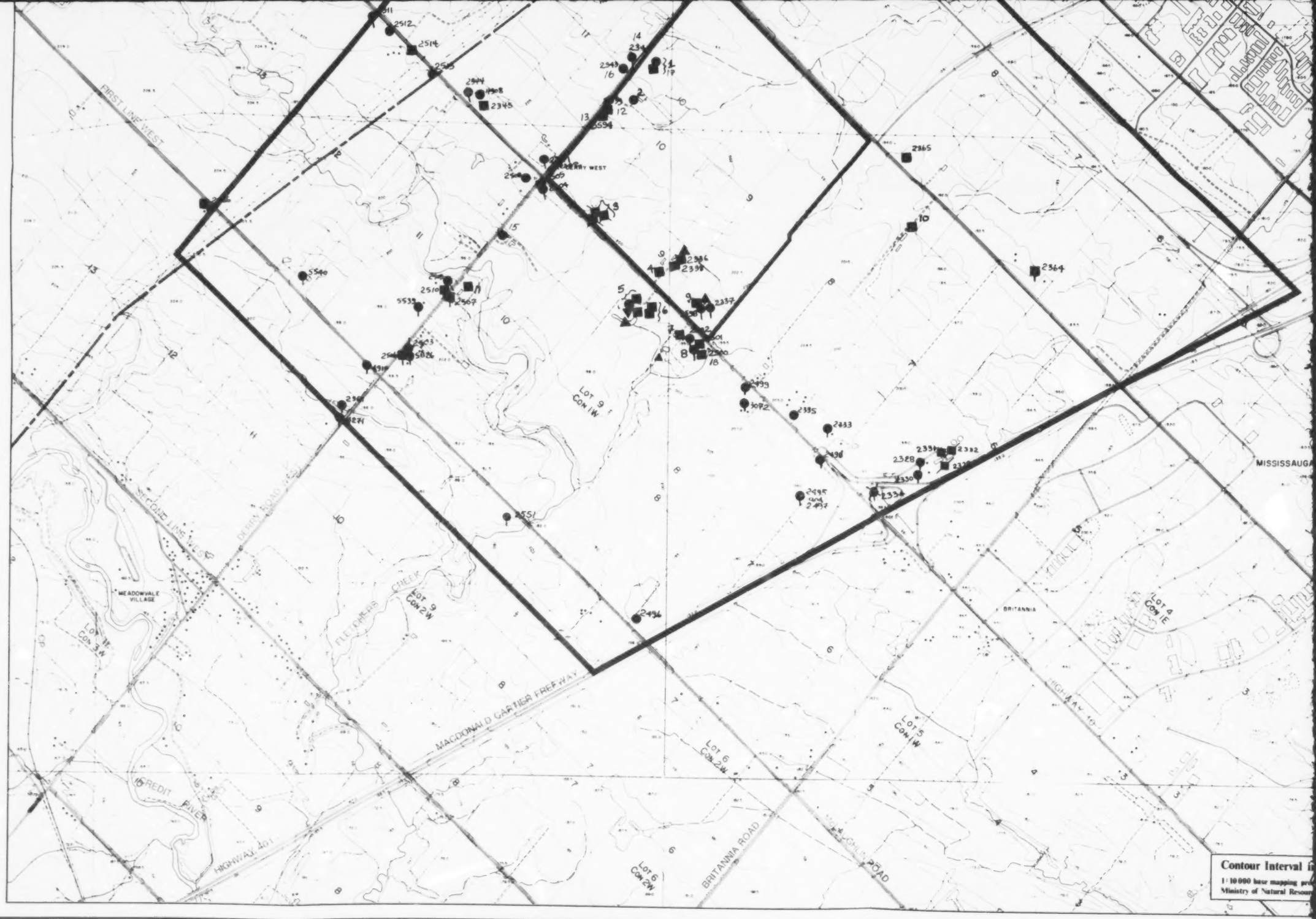
Phase 3B Acquisition Boundary **Site Vicinity Study Area Boundary**

Key Map:

LF-2 North

Lots 9 and 10; Concession I EHS (East of Hurontario Street), City of Mississauga



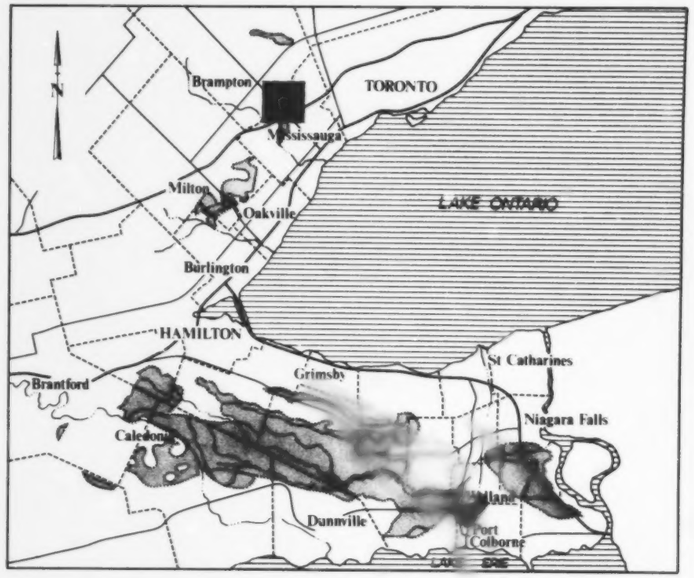

FIRST LINE WEST
SECOND LINE WEST
DERRY WEST
LOT 9 CON IW
MEADOWVALE VILLAGE
LOT 10 CON 3W
FLEWELLERS CREEK
LOT 9 CON 2W
CREDIT RIVER
HIGHWAY 401
MACDONALD CARTIER FREEWAY
LOT 6 CON 2W
BRITANNIA ROAD
LOT 5 CON IW
LOT 4 CON E
BRITANNIA
HIGHWAY 10
MISSISSAUG
Contour Interval
1:10 000 base mapping
Ministry of Natural Resou

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map:

LF-2 North

Lots 9 and 10; Concession I EHS (East of Hurontario Street), City of Mississauga



1000 feet 0 1000
500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Ground Water Use

September 1985

FIGURE 8

Contour Interval in Metres

1:10000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

Number/
Numéro

5

SITE SELECTION PROCESS - PHASE 4A

TECHNICAL APPENDIX LF-4N

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS

A REPORT PREPARED FOR
THE ONTARIO WASTE MANAGEMENT CORPORATION
BY
GARTNER LEE ASSOCIATES LIMITED

THIS REPORT IS ONE OF EIGHT TECHNICAL APPENDICES DESCRIBING GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS OF THE CANDIDATE SITES. IT SUPPORTS THE COMPARATIVE EVALUATION STUDY WHICH IS ENTITLED "SITE SELECTION PROCESS; PHASE 4A, SELECTION OF PREFERRED SITE(S), GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS".

SEPTEMBER, 1985

PROJECT 85-S18.3

Gartner Lee
Associates Limited

Gartner Lee Associates Limited

Consulting Engineering
Geologists
Biologists and
Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-477-8400
Telex-06-986278

September 20, 1985.

Dr. B.D. Mitchell,
Director of Corporate Planning
and Development,
Ontario Waste Management Corporation,
2 Bloor Street West,
11th Floor,
Toronto, Ontario,
M4W 3E2

Attention: Mr. J.G. Micak,
Manager,
Environmental Projects

Dear Dr. Mitchell:

Re: Site Selection Process - Phase 4A
Technical Appendix LF-4N - Geologic, Hydrogeologic,
and Geotechnical Considerations

Enclosed is our final report on the Geologic, Hydrogeologic and Geotechnical Considerations at Candidate Site LF-4N. Similar reports prepared for each of the other candidate sites will form the basis for site comparisons.

Thank you for allowing our company to be of service.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

E.G. Anderson, P.Eng.,
Project Director.

KJG:jcm
Enclosures.

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STUDY TEAM

This report was prepared under the overall direction of Grant Anderson, P.Eng., Project Director and Gunther Funk, Project Manager. Major contributing authors were:

Hydrogeology	Kenneth Goff
Geology	Andrew Cooper
Geotechnics	Douglas Jagger, P.Eng.
Field Co-ordination	Norbert Woerns

1.0 INTRODUCTION

1.1 BACKGROUND

The Ontario Waste Management Corporation (OWMC) site selection process to locate facilities for treating hazardous wastes and disposing of the treated waste residues, has been a phased process which began in 1981. Initial studies identified 261 hydrogeologic areas throughout southern Ontario which were grouped into six zones. Within the Golden Horseshoe, zone 1 and 2 lands were considered most favourable for facility siting. Twenty candidate areas were identified within the Zone 1 and 2 lands in the Golden Horseshoe in 1983. A total of 152 sites were identified in these twenty candidate areas in 1984 and this number was subsequently reduced in stages to sixteen potential sites and finally to eight candidate sites through the application of various constraints, screening processes, and ranking systems based on multidisciplinary factors. A more complete discussion of the site selection process is provided in the comparative evaluation study (GLAL 1985).

The present stage of study is the comparative assessment of the siting options. This Gartner Lee Associates Limited (GLAL) report documents and interprets available geologic, hydrogeologic, and geotechnical information for Site LF-4N and serves as the data source for input to the comparison study. The candidacy of this site is based on the potential development of either a landfill and/or treatment facilities consisting of a landfill and a physical chemical treatment plant.

The Phase 3B preliminary assessment of this site was

based primarily on existing data (GLAL 1984b). Phase 4A investigations described in this report add significantly to the geologic, hydrogeologic, and geotechnical data base.

1.2 OBJECTIVES AND SCOPE

The objectives of this study are to provide data for Site LF-4N to accommodate comparisons with the other siting options. These objectives have been met through additional investigations. The existing data base has been upgraded where possible and five boreholes have been drilled on the site. Each of the boreholes has been continuously sampled to provide detailed geologic logs and soil samples. Boreholes were not instrumented and were grouted on completion.

1.3 LOCATION

Site LF-4N is located in the Regional Municipality of Halton. It is shown together with the other candidate sites in Figure 1 and is presented in greater detail in the figures in the map pockets at the rear of the report.

The site under consideration on this technical appendix covers approximately 168 hectares (ha) and includes Lots 6 and 7, Concession 7, Town of Milton, formerly in the Township of Nelson. It is bounded on the northeast by Tremaine Road West (Regional Road 22), on the southeast by Britannia Road (Regional Road 6), and on the southwest by Bell School Line. The site is located within the corporate limits of the Town of Milton and is about 2 km south of the nearest built-up area. It is about 9 km south of Highway 401 and is roughly centered in a study area of about 2400 ha.

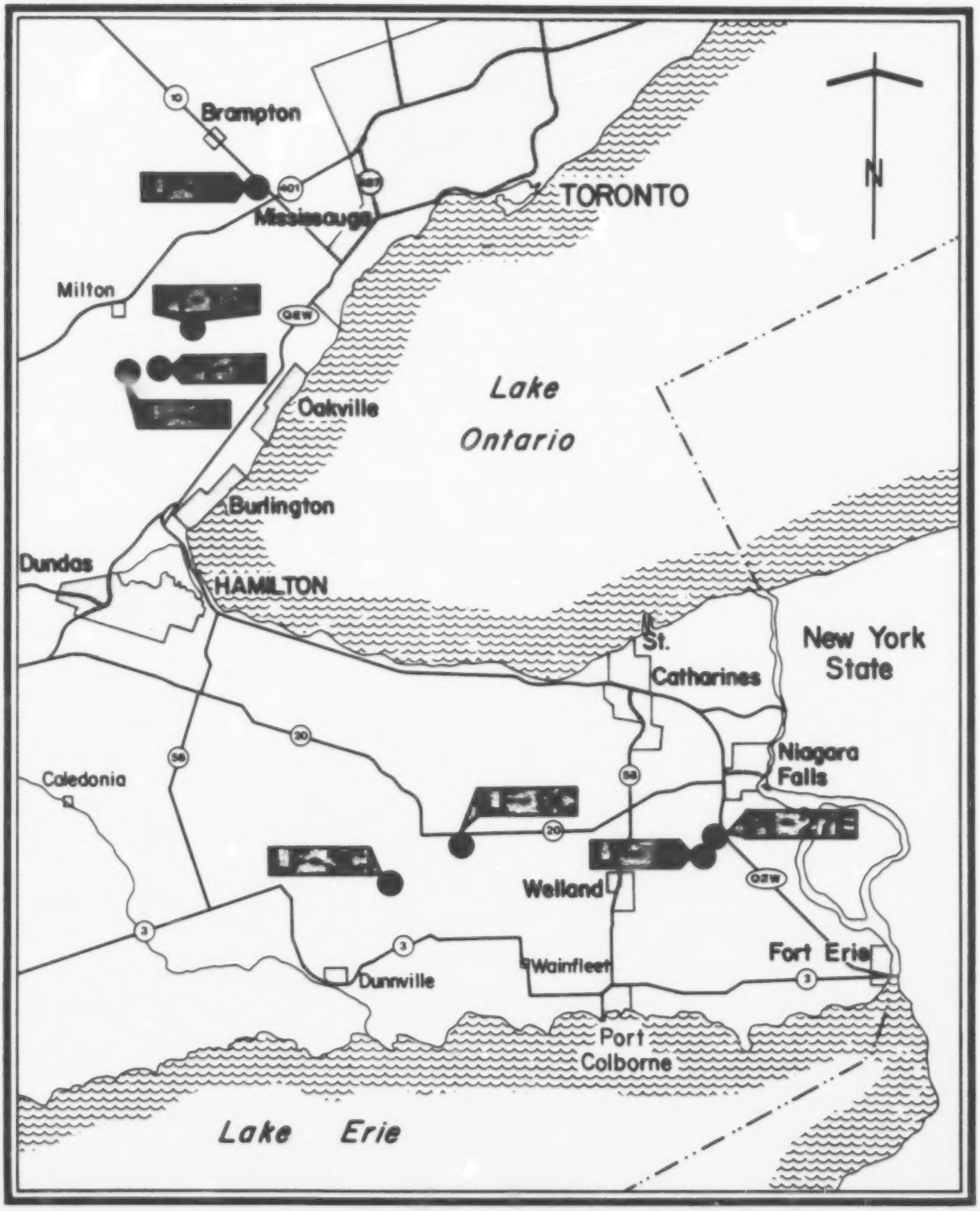


FIGURE 1 LOCATION OF CANDIDATE SITES

2.0 METHODOLOGY

The methodology employed in the collection, compilation and interpretation of the information base presented in this technical appendix report is described below and is illustrated in Figure 2.

2.1 DATA COLLECTION

The following sources of information were used:

- water well and borehole records, published and unpublished reports, maps, and "open file" reports;
- interviews with government agency personnel and local residents; and
- onsite drilling and field survey results.

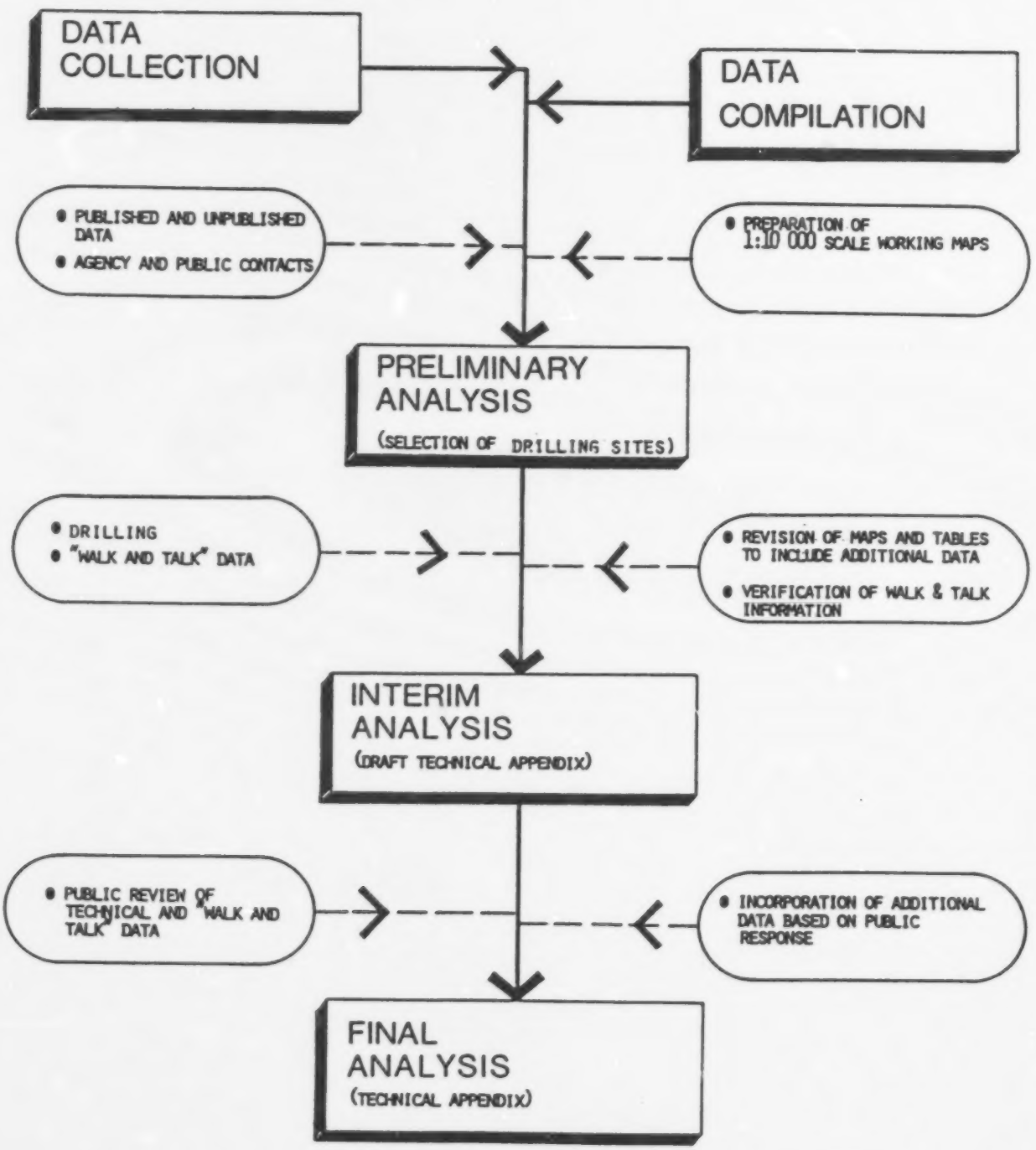
2.1.1 DATA BASE

Numerous reports and maps which contain both regional and local information on the geology and hydrogeology of the candidate sites were assembled during the earlier phases of the site selection process. Reports specific to this site are referenced in the text and are listed in Section 7.0. Data summaries are provided in Section 8.0

Supplementary information was collected with the co-operation of government and other agencies. This information includes:

Figure 2

Methodology Flow Chart


DATA COLLECTION
DATA COMPILATION
• PUBLISHED AND UNPUBLISHED DATA
• AGENCY AND PUBLIC CONTACTS
• PREPARATION OF 1:10 000 SCALE WORKING MAPS
PRELIMINARY ANALYSIS
(SELECTION OF DRILLING SITES)
• DRILLING
• "WALK AND TALK" DATA
• REVISION OF MAPS AND TABLES TO INCLUDE ADDITIONAL DATA
• VERIFICATION OF WALK & TALK INFORMATION
INTERIM ANALYSIS
(DRAFT TECHNICAL APPENDIX)
• PUBLIC REVIEW OF TECHNICAL AND "WALK AND TALK" DATA
• INCORPORATION OF ADDITIONAL DATA BASED ON PUBLIC RESPONSE
FINAL ANALYSIS
(TECHNICAL APPENDIX)

- copies of original water well records obtained from the Ministry of the Environment,

- copies of borehole information obtained from the Ministry of Transportation and Communications,

- copies of borehole information from previous GLAL hydrogeologic investigations,

- copies of borehole information from hydrogeologic investigations by other consultants.

These data are presented in Section 8.0. Copies of the data are on file.

2.1.2 INTERVIEWS

Additional information regarding site geology and water use was obtained during interviews with government agency personnel and local residents. The results of interviews are presented in the summaries prepared for agency meetings (by GLAL) and on resident interview forms (prepared by Ecologistics Limited). Meetings were held with the local public interest groups made up of residents and other interested individuals who identified items of geologic and hydrogeologic interest. The summaries of meetings and the interview forms are on file. Local water use information summarized from the interview forms is tabulated in Section 8.2.

2.1.3 DRILLING AND FIELD SURVEY RESULTS

Borehole locations were selected based on preliminary analysis of available data and input from the public. Five boreholes were completed at selected locations on the site to

confirm the expected character of the geologic materials. Drilling and sampling procedures are presented in the document entitled "Phase 4A Drilling and Sampling Activities and Protocol" (GLAL 1984a) and are summarized in the comparative evaluation study (GLAL 1985) and the detailed methods employed during this study are summarized in Section 8.6.

The drilling program involved the collection of continuous samples from boreholes. These samples were photographed and described in the field, placed in suitable containers and shipped to the Ontario Geological Survey in Toronto for storage. Split spoon samples were taken at 1.5 m intervals to obtain standard penetration values and samples for moisture content determinations in order to carry out preliminary geotechnical assessments. Detailed borehole logs were prepared based on the field descriptions and on subsequent examination of the samples in storage. These logs are presented in Section 8.3 as part of the supporting information package.

Only the 1984 GLAL, Morrison Beatty, and Hydrology Consultants boreholes (with the exception of Hydrology Consultants boreholes at Site PI-1N which fall within the study area) were continuously sampled. Other boreholes were sampled over intervals which are noted on the individual logs in Section 8.3. The 1976 and 1979 GLAL boreholes on and in the vicinity of Site LF-4N were generally sampled at 0.75 m intervals over the first 4.5 m and at 1.5 m intervals thereafter using standard split spoon methods.

2.2 DATA COMPILATION AND ANALYSIS

Data compilation and analysis has proceeded in a staged fashion which is depicted in Figure 2. In the initial work, primary information such as water well records was compiled in summary tables and illustrated on a series of working maps and cross-sections at a scale of 1:10 000. Maps included plots of:

- data point locations (all sources);
- geology (Ontario Geological Survey maps and reports, constraint mapping results from Phase 3B);
- bedrock elevations (water well and borehole data)
- confining layer thickness (water well and borehole data);
- aquifer thickness (water well data);
- aquifer information (water well data); and
- anomalies such as granular zones (water well and borehole data).

These maps were used to establish the geographic distribution of existing data points and to confirm at a more detailed scale the preliminary interpretation of geologic and hydrogeologic conditions as presented in the Phase 3B documentation (GLAL 1984b). Tentative drilling locations were then identified based on these preliminary analyses.

Following the selection of the tentative drilling locations, GLAL personnel met with interested parties to present the results of the preliminary analyses and to discuss the purpose and scope of the Phase 4A program. Additional information on local geologic and hydrogeologic conditions was collected during these meetings. (Water use information

provided by the public is incorporated in the water use portion of this report). Landowners and tenants were contacted at this time to obtain permission to drill on their properties and proposed drill site locations were modified based on local inputs.

A separate data collection program commonly referred to as the "Walk and Talk' survey was undertaken. During this survey, individual residents were interviewed by personnel from Ecologistics Limited and the results were recorded in a questionnaire format. Among the multidisciplinary questions were several which were provided by Gartner Lee Associates Limited and which related specifically to water supply and use. The collection of ground water information and related water use data was limited primarily to the site and to adjacent properties.

With the completion of the drilling and public survey programs, the working maps were revised to incorporate the additional information that was collected. This technical appendix presents an interpretation of geologic, hydrogeologic, and geotechnical conditions at LF-4N to date. Draft copies of the data summaries were circulated to the local interest groups as a check for completeness and accuracy.

3.0 REGIONAL GEOLOGY AND HYDROGEOLOGY

The geology and hydrogeology of the Halton-Peel area are summarized and discussed in reports prepared for the Ontario

Waste Management Corporation (GLAL 1984b,c). This section is based on these reports and the reader is referred to them for more detail and for a complete list of references on which they are based.

3.1 REGIONAL GEOLOGY

3.1.1 BEDROCK GEOLOGY AND OVERBURDEN THICKNESS

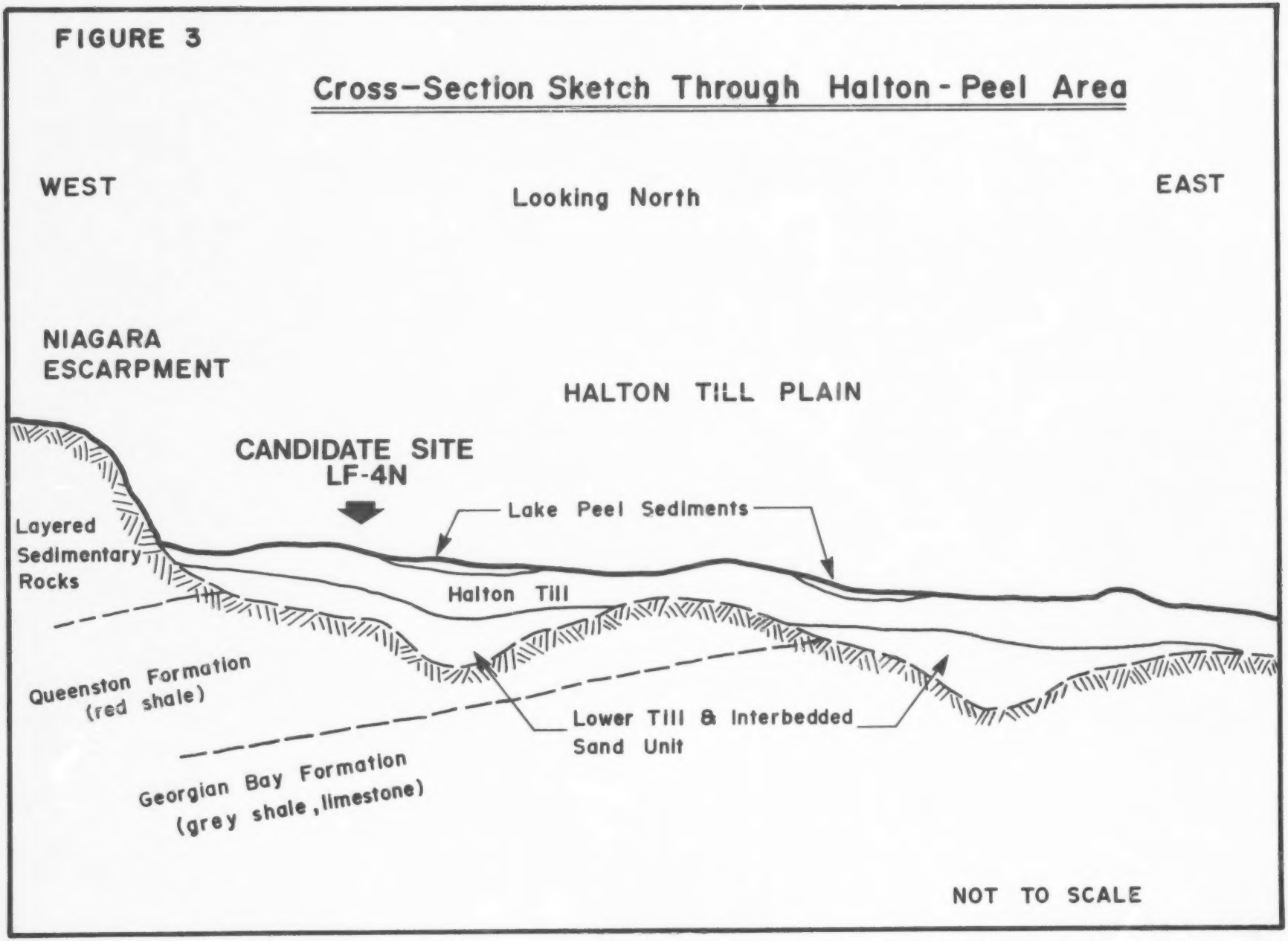
Bedrock in the south-central portion of Ontario consists of a series of sedimentary rock formations which dip gently to the southwest. The various rock formations are consequently exposed on the buried bedrock surface in a series of northwest-southeast trending bands which become progressively younger from northeast to southwest. Figure 3 shows the approximate location of Site LF-4N on a generalized cross-section from the Niagara Escarpment southeastward to Lake Ontario. In the Halton-Peel area, bedrock is the Georgian Bay Formation (grey shale and limestone) in the east and the Queenston Formation (reddish-brown shale) in the west. Generally, the bedrock surface is similar to the present land surface and slopes gently from the Niagara Escarpment to Lake Ontario. Bedrock usually occurs within 10 m of the ground surface and creek valleys are commonly eroded into the bedrock. Occasional buried valleys and depressions occur on the bedrock surface and where these are infilled, the drift may be substantially thicker. At several locations, water courses have reoccupied portions of the bedrock valleys (examples are Sixteen Mile (Oakville) Creek and the Credit River).

3.1.2 QUATERNARY GEOLOGY

Good geologic exposures are infrequent and there has been

FIGURE 3

Cross-Section Sketch Through Halton - Peel Area



Gartner Lee Associates Limited

little published geologic survey work in the area to date. Available information is summarized and referenced in a previous OWMC report (GLAL 1984c).

Quaternary units are summarized in Figure 3. In view of the lack of detailed geologic studies in the area, only the uppermost till unit (Halton Till) and the surficial glaciolacustrine Lake Peel sediments are referred to by formal names. From oldest to youngest the units are: (1) a lower till and interbedded sand unit which directly overlies the bedrock, (2) the Halton Till, and (3) the Lake Peel glaciolacustrine sediments. The lower till and sand unit may locally contain subunits but it is regarded as a single unit on a regional level. Till textures in this unit are commonly silty and sandy and sand inclusions occur both within and between tills. It is possible that the Wentworth Till is part of this unit (GLAL 1984c). The Halton Till is clayey silt to silt in texture and the surficial Lake Peel sediments consist of an intermittent veneer of sands, silts, and clays.

The geologic events associated with these deposits began with a series of ice sheet advances and retreats which led to the deposition of the lower till and interbedded sand. Glaciolacustrine and/or glaciofluvial sands, silts and clays were deposited between glacial advances and have been preserved between the till sheets at some locations. The last ice advance occurred about 12 000 to 13 000 years ago and laid down the Halton Till. The character of the till suggests a fluctuating ice margin, possibly with a glacial lake in front of the ice. Several subunits are known within the Halton Till and are occasionally separated by thin beds of silt, clay or sand (GLAL 1984c). A series of shallow, short-lived lakes were formed on

the Halton Till during the final melting and retreat of the ice. These are responsible for a discontinuous veneer of sand, silt and clay which is collectively known as the Lake Peel sediments. Since the final glacial retreat, the Halton Till and Lake Peel sediments have been subjected to weathering and erosion to produce the present landscape.

3.2 REGIONAL HYDROGEOLOGY

Figure 3 indicates geologic and hydrostratigraphic units which have been used in reports and publications for the Halton-Peel area (GLAL 1984b,c). Each of the units is discussed in a regional context beginning with the bedrock and proceeding through the overburden from oldest to youngest.

The upper fractured portions of both the Queenston and Georgian Bay formations are sources of water supply. Regionally, they are considered poor aquifers as yields are generally low and water quality may be marginal to poor. However, where drift aquifers are not present, it is the only aquifer available. On a regional scale, ground water flow in the upper bedrock is toward Lake Ontario, however local flow patterns may be altered as a consequence of valleys and depressions.

Buried sand and gravel deposits in the region are summarized and mapped in previous reports (GLAL 1984b). Thin, discontinuous sand and gravel layers between tills or directly above bedrock occur in the LF-4N study area. Local water supplies are usually developed either in the upper fractured portion of the bedrock or in these granular deposits.

Tills within the lower till and interbedded sand unit vary in texture from silty sand to silt and clayey silt. Sand and silt laminae and interbeds are common but vary in thickness, continuity, and hydraulic conductivity. Large diameter dug or bored wells which appear to be completed in this unit likely obtain water from sand interbeds.

The Halton Till is clayey silt to silt in texture and is a hydrostratigraphic unit of regional extent. Ground water movement through it is very slow because of its fine texture and low hydraulic conductivity. Dug and bored wells occasionally obtain water from the surficial fractured zone, however most supplies are obtained from the bedrock and from granular zones within the lower till and interbedded sand unit. Alluvium may also provide water supplies to shallow dug and bored wells where such wells are completed in flood plain deposits in the region.

4.0 SITE GEOLOGY AND HYDROGEOLOGY

Interpretations of the geology and hydrogeology of Site LF-4N take into account the regional data together with the new GLAL borehole information. In addition, data from formal and informal field interviews are integrated into this analysis. Figure 4 (in map pocket) provides locations of the cross-sections and the field data presented in this report.

Requests from the GLAL borehole program at this comparative evaluation stage are used to confirm the geology and

hydrostratigraphy and to evaluate the predictability and uniformity of subsurface conditions. Hydrogeologic discussions are based on the geology and on such additional sources of information as water well and borehole records and water use data provided by local residents. Table 1 compares local geologic and hydrostratigraphic units for the site and vicinity. This table provides the framework for the discussions that follow, from bedrock to surface.

TABLE 1: SUMMARY OF LOCAL GEOLOGIC AND HYDROSTRATIGRAPHIC UNITS

GEOLOGIC UNIT	HYDROSTRATIGRAPHIC UNIT	
HALTON TILL	CONFINING LAYER	FRACTURED ZONE (HALTON TILL)
		HALTON TILL
LOWER TILL AND INTERBEDDED SAND	UPPER SAND	UPPER SAND AQUIFER
	LOWER TILL & SAND	LOWER TILL AND SAND AQUIFER
	BASAL SAND	BASAL SAND AND BEDROCK AQUIFER
BEDROCK (QUEENSTON SHALE)		

Note: The 'upper sand aquifer' and the 'basal sand aquifer' are present along the trend of the bedrock valley and absent beneath the southern and northern portions of the site.

4.1 SITE GEOLOGY

Five continuously sampled boreholes were drilled on Site LF-4N in 1984 by Gartner Lee Associates Limited. Additional onsite boreholes include; ten drilled by GLAL between 1976 and 1979 for the Region of Halton (GLAL 1980); four drilled by Morrison Beatty Limited in 1984 for the Town of Milton and two drilled by Hydrology Consultants Limited in 1984 for the Region of Halton. In addition, three test pits dug to depths of about 3 m are described in the 1980 GLAL report. Two Ministry of Transportation and Communications boreholes are located immediately south of the site. All boreholes and wells are identified on Figure 4.

Boreholes drilled in 1984 by GLAL, Morrison Beatty Limited and Hydrology Consultants Limited (with the exception of Hydrology Consultants Limited Borehole D-6) were continuously sampled. Other boreholes were sampled at intervals indicated on the borehole logs in Section 8.3. The 1976-1979 GLAL boreholes were generally sampled at 0.75 m intervals for the first 4.5 m and at 1.5 m intervals thereafter using standard split spoon methods.

Geologic cross-sections through the study area are presented in Figures 5 and 6 (in map pocket). The geologic names in the borehole logs (e.g. Halton Till) are used to relate local geology to the established geologic framework and are based on published descriptions. Cross-section geologic descriptions are simplified for presentation. Supporting borehole logs and water well logs are presented in Section 8.0.

4.1.1 TERRAIN

Site LF-4N is located on the Halton Till plain which is level to gently rolling. Slopes are toward the southeast except where the plain is dissected by stream erosion. Surface elevations range from about 188 m (above sea level) in the north to about 179 m in the south adjacent to a stream channel. Drainage is generally via grassed swales which convey intermittent flows to Indian Creek.

4.1.2 BEDROCK GEOLOGY AND DRIFT THICKNESS

All five boreholes encountered reddish-brown, thinly bedded calcareous siltstones and interbedded shales. Descriptions of the bedrock are similar to those provided by Telford et al. (1976) and are considered to indicate the Queenston Formation.

The site overlies a broad, buried bedrock valley which trends in a generally east-west direction through the central part of the site and also extends eastward beneath Site PI-1N. The shape of the valley is indicated on Cross-Section A-A' (Figure 5) which shows rising bedrock to the south and north.

Overburden thicknesses on the site range from about 15 m in the north and south to about 40 m at the eastern extremity of the site. Thicknesses are greatest along the trend of the bedrock valley from east to west.

At some locations the shale bedrock is overlain by a dense, clayey, reddish deposit which contains numerous shale fragments. This deposit is gradational between the overburden and the bedrock and has sometimes been termed the shale-till complex (GLAL 1980).

4.1.3 LOWER TILL AND INTERBEDDED SAND UNIT

Up to three tills and several sand layers of varying texture and thickness comprise the 'lower till and interbedded sand' unit which was encountered between the bedrock and the Halton Till in the 1984 GLAL boreholes. The tills have clayey, silty, and sandy textures and are characteristically interbedded with sand. The unit is distinguished from the overlying Halton Till by its slightly coarser textures and greater variability. It appears to be continuous beneath the site becoming thicker and more variable over the bedrock valley (Figures 5 and 6). Laminae, beds, and inclusions of sand were encountered within the unit in most boreholes. Thicknesses of these granular zones range up to 6 m and textures vary from silty fine sand to gravelly medium sand.

Preliminary interpretations of the geologic data at Site LF-4N indicate the presence of three subunits of the 'lower till and sand' which are most readily identified along the trend of the bedrock valley. Contacts of these subunits in Figures 5 and 6 identify general geologic trends and conditions and comply with most of the borehole data. Contacts should be regarded as approximate because subunits commonly grade into one another and because sand and till zones are often interbedded. From oldest to youngest, these subunits are (1) a basal sand on or near the bedrock surface, (2) a lower till and sand deposit, and (3) an upper sand which occurs immediately below the Halton Till.

The 'basal sand' is absent beneath the northern and southern portions of the site. It appears to be limited to the bedrock valley and is thickest along the trends of the valley. It is contained by rising bedrock to the north and south (Figure 5), but appears to have continuity along the bedrock

valley (Figure 6). This subunit varies in texture from silt to gravelly coarse sand. It rests directly on bedrock in Boreholes GL84-1 and -2 and is separated from bedrock by 2.9 m of clayey silt till in Borehole GL84-4. The basal sand ranges between 2.1 and 6.5 m in thickness in the GLAL (1984) boreholes.

The 'lower till and sand' subunit extends from the base of the Halton Till to the bedrock in northern and southern portions of the site where the basal and upper sand subunits are absent. It is thickest along the axis of the bedrock valley and thicknesses range from about 7 m to 14 m across the site. Textures are variable tending to be clayey silt in lower portions and sandy silt in upper portions. A sandy interval occurs in the 'middle' of this subunit in Borehole GL84-2 in association with laminated clayey silts (which also occur in Borehole GL84-4). Thin, sandy, silty, and clayey beds occur randomly throughout this subunit.

The 'upper sand' subunit separates the Halton Till from the underlying lower till and sand in the central portion of the site. It is most evident in Boreholes GL84-1 and -4 and probably correlates with the sandy till interval between 18.8 and 21.9 m in Borehole GL84-2 which contains 'sand interbeds to 30 cm and sandy zones'. Thicknesses range up to 2.9 m (Borehole GL84-1) and textures vary from silt and fine sand to coarse sand and fine gravel.

4.1.4 HALTON TILL

The uppermost till encountered in all onsite boreholes is the Halton Till (Karrow 1963). It is commonly clayey silt in texture and ranges between 7 m and 19 m thick. It is thickest

along the east-west axis of the bedrock valley and thinner to the north and south where bedrock is shallower. The upper portion of the till is heavily fractured to depths of 1 to 2 m with fractures common to approximately 4 m. Colour changes from browns to greys usually occur between 4 and 6 m. Several thin silt and silty sand laminae and beds were observed within the Halton Till. These occurrences are noted in three of the five 1984 GLAL boreholes and are most common in the 5 to 7 m depth range; however, there is not sufficient evidence to indicate that they form a continuous sandy zone.

4.1.5 ALLUVIUM

Only a small area in the extreme southern part of the site (adjacent to Indian Creek) may be underlain by alluvium. Based on available source materials, these deposits would likely be fine textured.

4.1.6 DISCUSSION

The Halton Till is continuous beneath the site and is thickest along the axis of the buried valley. It is considered to be relatively uniform and predictable. The 'underlying lower till and interbedded sand' unit is texturally and stratigraphically variable. Apparently continuous granular zones occur within the upper portion of this unit and at the till-bedrock interface.

4.2 SITE HYDROGEOLOGY

The Phase 4A field work incorporates first-hand geologic descriptions and interpretations with the existing data base (primarily water well record and borehole information). Hydrogeologic analyses utilize borehole geology, water well and

borehole records, information provided by the public, and information supplied by researchers in similar hydrogeologic settings together with the experience of Gartner Lee Associates Limited staff. Descriptions of the hydrostratigraphic units, flow systems, ground water use and potential contaminant pathways are presented in the following sections.

4.2.1 HYDROSTRATIGRAPHY

Four major hydrostratigraphic units occur at Site LF-4N. From bottom to top they are: (1) the fractured bedrock and basal sand aquifers, (2) the lower till and sand aquifer, (3) the upper sand aquifer and (4) the confining layer (Table 1). Aquifers at Site LF-4N are the shale bedrock and the various sand layers below the Halton Till. The confining layer terminates at the base of the Halton Till. The unfractured portion of the Halton Till is the least permeable hydrostratigraphic unit on the site.

4.2.1.1. Bedrock and basal sand aquifer

The Queenston shale is an important source of water to drilled and bored wells. About half the approximately sixty-five recorded (MOE) wells in the study area obtain water from the shale and about half of these encounter adequate supplies within 5 m of the bedrock surface. It is considered that fractures are the primary source of water in the shale and that fracturing generally decreases with depth. The shale is generally a low-yield aquifer but it is locally important where granular aquifers are absent. Test pumping rates reported during development in bedrock wells are generally low and range from approximately 0.01 to 0.7 litres per second on and adjacent to the site.

The average hydraulic conductivity of the fractured shale is estimated to be approximately $8x10^{-7}$ m/s based on pumping test data from water well records on and immediately adjacent to the site and calculations described by Walton (1962) and Ogden (1965). Hydraulic conductivities in the Queenston shale at the Oakville landfill site also averaged about $5x10^{-8}$ m/s (GLAL 1981).

The 'basal sand' occurs within the bedrock valley on or near the bedrock surface. As there are few wells on or adjacent to the site, it is impractical to assess the yields of the various sand layers; however, numerous sand (and gravel) layers are reported and several are utilized for water supplies (Table 4, Section 8.1). The texture of the 'basal sand' varies, ranging from silt to fine sand in Borehole GL84-1 to silty sandy gravel in Borehole GL84-2. The average hydraulic conductivity of the basal sand is considered to be about $1x10^{-6}$m/s which is within the range of values for silty sand provided by Freeze and Cherry (1979).

4.2.1.2 Lower till and sand aquifer

This unit may contain up to three tills and several sand interbeds. Where the sand beds are sufficiently thick and continuous, they are considered to have aquifer potential. Till textures range from clayey silt to silty sand. The 'lower till and sand' unit is excluded from the confining layer because of its variable texture and the presence of a sand layer (upper sand aquifer) at the top of the unit. Although the hydraulic conductivity of the 'lower till and sand' unit is variable and depends on textural composition, an average vertical hydraulic conductivity of $1x10^{-7}$ m/s is considered representative.

Granular layers which form part of the 'lower till and sand' unit vary in texture from silty fine sand to fine gravel and are usually silty. Their thicknesses ranges from a centimetre or less to about 6 m and they occur most frequently below depths of about 15 m. These deposits are sources of water to many wells in the study area. Yields to drilled wells completed in granular deposits on and adjacent to the site range from 0.8 to 2 L/s. Some dug and bored wells in the study area appear to terminate in the till deposits (Table 4, Section 8.1), however it is likely that supplies are obtained from granular zones within the till.

4.2.1.3 Upper sand aquifer

The upper sand aquifer occurs along the axis of the bedrock valley in an east-west band across the central part of the site. It is thickest over the central portion of the valley and pinches out to the north and south. It is difficult to distinguish this sand from others in the underlying unit in water wells since the available records (Section 8.1) do not usually provide detailed stratigraphic descriptions. The sand is considered to have aquifer potential based on its thickness, continuity and texture and is assigned an average hydraulic conductivity of 1×10^{-6} m/s which is intended to reflect its generally fine texture. This value is within the range applied to silty sand by Freeze and Cherry (1979).

4.2.1.4 Confining layer

The confining layer is comprised of fractured and unfractured Halton Till. The thicknesses of each of these subunits is noted in Table 2 along with selected hydrogeologic parameters.

TABLE 2: SUMMARY OF CONFINING LAYER CHARACTERISTICS

BOREHOLE / PARAMETERS	CONFINING LAYER SUBUNITS		CONFINING LAYER THICKNESS (m)
	UNFRACTURED HALTON TILL (m)	FRACTURED HALTON TILL (m)	
GL84-1	9.1	5.0	14.1
GL84-2	13.8	5.0	18.8
GL84-3	3.3	5.0	8.3
GL84-4	14.4	5.0	19.4
GL84-5	5.6	5.0	10.6
Average hydraulic conductivity (m/s)	$1x10^{-9}$	$1x10^{-7}$	
Average porosity	0.3	0.0001	

Notes:- Unfractured porosity values are estimates of total intergranular porosity.
- The fracture porosity value is the effective fracture porosity reported by Desaulniers (1982).
- Porosity values in the unfractured materials reflect intergranular porosity. Additional fracture porosity is present in the fractured zone. These fractures are accompanied by increased hydraulic conductivities with the result that ground water can potentially move more rapidly along fractures.

Hydraulic conductivities for the unfractured portion of the Halton Till are based on a previous GLAL (1980) report for this site. This report indicates a maximum hydraulic conductivity value of $1x10^{-9}$ m/s from in situ slug tests and a value of $5x10^{-10}$ m/s using a triaxial laboratory apparatus. Based on this information, an average hydraulic conductivity of $1x10^{-9}$ is assigned to the unfractured Halton Till.

Silt to medium sand deposits up to 0.3 m thick occur within the Halton Till in some of the 1984 GLAL boreholes at depths between 5 and 7 m. It is possible that these zones could provide small supplies to dug or bored wells at some locations, however they are considered to be too thin and too fine grained to be regarded as aquifers. A previous report (GLAL 1980) indicated a hydraulic conductivity of $1x10^{-7}$ m/s for a 0.5 m thick silty sand layer at a depth of 7.6 m on this site. This value occurs at the lower end of the range for silty sand given by Freeze and Cherry (1979). Porosity is estimated to be about 0.3.

The upper portion of the confining layer at Site LF-4N is heavily fractured in the upper 1 to 2 m and fractures are common to depths of about 4 m according to 1984 GLAL borehole logs. Test pit observations (GLAL 1980) at three locations on the site indicated an absence of fracturing below depths of about 2.5 m. Freeze and Cherry (1979) note that deposits of clayey or silty till and glaciolacustrine deposits in southern Ontario contain networks of hairline fractures which are essentially vertical and which are responsible for hydraulic conductivities one to three orders of magnitude greater than in unfractured materials. Based on this information, fracturing is considered to be responsible for a permeability difference of about two orders of magnitude between the fractured zone and the unfractured zone and a hydraulic conductivity of $1x10^{-7}$ m/s is applied to the fractured zone. An effective fracture porosity of 0.0001 is assigned to the fractured zone based on Desaulniers' (1980) data.

Confining layer thicknesses are shown on Figure 7 (in map pocket) for boreholes and for wells for which MOE well records are available.

4.2.1.5 Discussion

The confining layer consists of fractured and unfractured Halton Till. It ranges between 15 and 20 m thick across the central third of the site (above the bedrock valley) and is probably less than 10 m thick over about a quarter of the site in the north and south. Although the confining layer thickness does vary across the site, thickness is related to bedrock topography and appears to be relatively predictable. Thin sandy zones in parts of the confining layer indicate some textural variability, but these are considered too thin and too fine textured to interrupt the confining layer.

4.2.2 GROUND WATER FLOW REGIME

Infiltration is the source of ground water and differences in hydraulic head provide the driving force for ground water flow systems. At Site LF-4N, a shallow, lateral flow system is considered to exist in the saturated portion of the fractured zone of the Halton Till. Ground water flow in the unfractured drift is essentially vertical since vertical gradients are substantially greater than horizontal gradients. There is potential for lateral flow in more permeable granular layers. Where bedrock is in good hydraulic connection with the basal sand deposits, they may form a single hydrostratigraphic unit in which flow is primarily lateral.

The water table occurs in the fractured zone and its shape is usually a reflection of topography. Fracture density decreases rapidly to the base of the fractured zone which occurs on the site. The shallow flow system is most active in the near-surface saturated zone where fracturing is common and where fracture permeability is best developed. Movement in the shallow flow system is essentially lateral and rates and directions of flow are dependent on elevation differences in the

water table. Topography slopes southward and southeastward on the site at a gradient of about 0.004 and water table mapping for the site (GLAL 1980) indicates a similar water table gradient and direction. Discharges would be expected to occur to local drainage channels and topographic lows.

Applying a hydraulic conductivity of $1x10^{-7}$ m/s, a fracture porosity of 0.0001, and an average lateral water table gradient of 0.004 to Darcy's Law yields a linear ground water velocity of about 100 m per year. A potential discharge area for this shallow flow system would be along Indian Creek. Estimates of fracture flow rates are usually large relative to intergranular flow rates because of very small fracture porosity values. Fracture flow rates are considered to be unrealistically large if the rates are interpreted as 'straight-line' flow pathways because fracture interconnections are generally complex and interconnections that do exist are usually indirect.

Table 3 presents a summary of average vertical ground water flow rates which apply in the confining layer. An average downward hydraulic gradient of 0.1 was calculated by comparing the reported static water levels in onsite and adjacent water wells with a water table assumed to be at ground surface. This method likely produces steeper downward gradients than actually exist since downward gradients less than 0.01 are indicated in existing piezometers on the site and upward hydraulic gradients occur at some locations (GLAL 1980). Downward ground water velocities in the unfractured confining layer are calculated to be about 0.02 m per year based on the 0.1 gradient.

TABLE 3: ESTIMATED RATES OF VERTICAL FLOW IN THE CONFINING LAYER

BOREHOLE	UNFRACTURED ZONE m/s	FRACTURED ZONE m/s
GL1	5×10^{-10}	2×10^{-6}
GL2	5×10^{-10}	2×10^{-6}
GL3	8×10^{-10}	2×10^{-6}
GL4	4×10^{-10}	1×10^{-6}
GL5	2×10^{-10}	2×10^{-6}

Note: Multiply by 3.15×10^{7} for flow rates in metres per year.

Thicknesses of confining layer subunits and selected hydrogeologic parameters are provided in Table 2.

The hydrogeologic significance of granular deposits is dependent on their extent and continuity. If they are of limited areal extent and encapsulated as lenses in the till, they will not significantly affect rates or directions of ground water flow. However, if they are continuous they may provide conduits for offsite ground water movement. Since the textures of the granular strata reported in GLAL boreholes are variable (silts, silty fine sands, and silty gravels), the hydraulic conductivities and ground water flow rates will also vary.

For a more accurate discussion of ground water flow rates through the confining layer based on advection and diffusion calculations, the reader is referred to Appendix A of the report entitled "Site Selection Process' Phase 4A. Selection of Preferred Site(s), Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

The upper sand and the basal sand aquifers (which occur in the bedrock valley on or near the bedrock) are considered continuous and are potential conduits for offsite ground water movement. The hydraulic conductivity of the sand aquifers is estimated to be $1x10^{-6}$ m/s (Section 4.2). Applying this value to Darcy's Law along with a lateral gradient of 0.004 (same as the water table gradient) and a porosity of 0.3 would result in an estimated lateral flow rate of about $1x10^{-8}$ m/s or 0.5 metres per year. Rates of movement in the sand deposits could be larger if gradients are greater or if higher hydraulic conductivities prevail along the valley. Flow in the sand aquifers probably occurs along the bedrock valley from east to west (in the direction of the deepening valley). Ground water which is recharged at the surface would not be available for lateral flow in such deposits until it had passed through the confining layer.

Previous investigations at the site (GLAL 1980) indicate southerly gradient of about 0.003 for the upper portion of the bedrock. Applying this value together with an average hydraulic conductivity of $8x10^{-7}$ m/s and a porosity of 0.001 to Darcy's Law produces an annual average rate of flow of about 100 m per year. The regional direction of flow is

generally toward Lake Ontario, however local components of flow toward and along the buried bedrock valley are also possible.

As indicated previously, fracture flow rates may be unrealistically large if they are interpreted over 'straight-line' distances since fracture connections are usually complex and interconnections may be indirect or poorly developed.

4.2.3 GROUND WATER USE

Water use information is based on water well record data and on information collected from residents and landowners on the site and on directly adjacent properties.

4.2.3.1 Availability

Water supplies for domestic, stock and general agricultural purposes are obtained from dug/bored wells, drilled wells, cisterns, and ponds. Water use information is summarized according to source in Figure 8 (in map pocket) and is supported by a summary table in Section 8.2.

Based on water well records and field information surveys, it appears that both drilled wells and dug/bored wells are important sources of water supply in the study area. Wells completed in the shale bedrock predominate in areas of shallow bedrock while overburden wells predominate in central portions of the site where bedrock is deeper (along the trend of the buried bedrock valley). Available data indicate that bedrock and overburden wells in the study area generally have low yields, however most residents are able to obtain sufficient quantities of ground water to meet their domestic and

agricultural needs. Three of five residences on the site reported the use of cisterns for general domestic purposes or livestock watering or as back-up systems to wells. Dugouts or ponds are reported on slightly less than half the residences on the site and the adjacent area and some of these are used for livestock watering and general agricultural purposes.

4.2.3.2 Quality

Water quality problems are reported for some of the deeper bedrock wells. One drilled well on the site has been abandoned because of poor quality and others are used for agricultural purposes only. Most of the water well records report 'fresh' water and most residents interviewed, indicated their water was 'hard' but acceptable for drinking.

4.2.4 POTENTIAL CONTAMINANT PATHWAYS

In general, there are two hydrogeologic pathways by which contaminants can potentially leave the site; these are (1) natural pathways along ground water flow systems and (2) man-made pathways along such structures as abandoned and unplugged wells, tile drains, and underground service trenches. Natural pathways through the confirming layer tend to retard contaminant movement as a result of low hydraulic conductivity and gradient and are discussed in the sections on Site Hydrogeology (4.2.1) and Ground Water Flow Regime (4.2.2).

Efforts have been made to identify and locate man-made structures such as water wells, gas wells, tile drainage systems, pipelines and excavations which may be located on

the site. These structures could act as conduits or pathways along which contaminants could move. For example, improperly sealed or abandoned wells which penetrate the confining layer could provide access to underlying aquifers. Shallow structures such as granular trench backfill and drainage tiles could provide access to surface water and shallow ground water. A total of fourteen wells are known on the site. Four of these are on record with the Ministry of the Environment and ten additional wells were identified during the "Walk and Talk" interviews. Of these 14 wells, six are bored/dug (three are unused or abandoned), seven are drilled (one is unused and one is abandoned because of poor quality), and one is of unknown type.

In addition to water wells, the site has been the subject of drilling programs for the purpose of other hydrogeologic investigations. The present GLAL investigation involved the construction of five boreholes which were grouted with a cement-bentonite mixture on completion (no monitors were installed). Other studies in 1984 by Morrison Beatty Limited and by Hydrology Consultants Limited resulted in a total of six boreholes which were equipped with piezometers. In 1976 and 1979 GLAL drilled eight locations on Site LF-4N and installed piezometers in the boreholes. The piezometers extend to a variety of depths and each is sealed to ensure that it monitors water levels in a selected interval.

Gas wells are not common in this area. Ministry of Natural Resources records indicate no onsite wells, however one resident stated that an oil or gas well had been drilled

on Lot 5, Concession 7. Present information indicates that none of the site is tile drained and excavations are believed to be limited to the immediate vicinity of buildings. The presence of buried service trenches along roadways was not investigated.

5.0 GEOTECHNICAL CONSIDERATIONS

This section of the report provides a preliminary assessment of Site LF-4N from a soils engineering viewpoint. The geologic setting is described in detail in Section 4.0 of this report.

The geologic data base has been supplemented by standard split-spoon penetration tests taken at approximately 1.5 m intervals in each of the five GLAL boreholes. The standard penetration (N) values have been used as a guide in estimating the relative density and consistency of the various soils. Shear strengths noted here were estimated by correlating the N values with empirical shear strength relationships. Moisture contents are presented along with N values on the geologic logs in Section 8.3.

A desiccated crust is associated with the upper weathered zone of the Halton Till. This crust has a relatively consistent thickness of about 4 m. It is hard as indicated by N values of 33 to 73 (blows per 0.3 m) and has an undrained shear strength in excess of 200 kPa. The in situ moisture

content was typically 10 to 14%, although locally higher moisture contents were observed.

A weaker stratum occurs within the Halton Till beneath the desiccated crust. This stratum varies in thickness from approximately 4 to 16 m across the site. The N values range from 10 to 28 suggesting that the consistency of the soil is stiff to very stiff. Based on the N values, the undrained shear strength is about 75 to 200 kPa. The in situ moisture content typically ranges from 10 to 15%, although locally higher values were observed.

In some parts of the site a thin layer (1 to 3 m thick) of hard till occurs beneath the weaker stratum. Standard penetration resistance (N) values in this layer are 35 to 50 and corresponding undrained shear strengths are likely to exceed 200 kPa. Moisture contents are in the 9 to 25% range.

Deeper tills are very dense with N values greater than 50. In situ moisture contents vary from 6 to 23% with the higher values associated with more silty and sandy intervals. There are beds of very dense, saturated sand within the lower till.

Preliminary assessments based on the data from GLAL boreholes indicate that geotechnical conditions are generally adequate for site development from a soils engineering point of view. However, proper design should be carried out within the framework of the following geotechnical guidelines. All geotechnical aspects will require further investigation during the Phase 4B work at the preferred site.

Temporary excavations can be safely carried out to depths of 15 m within the Halton Till at side slopes of 2:1. Preliminary calculations indicate that excavations should not terminate within 4 m of buried sand seams as a safeguard against heave. Where excavations intersect saturated sand layers, ground water control will likely be necessary.

Treated waste residues could be generally placed to thicknesses of about 1.5 times the depth of the cells (based on a waste density of 1.35 tonnes per cubic metre) without creating a surcharge load. Provided there is no surcharge load within the cell base, settlement will be minimal. As well, no problems related to bearing pressure are anticipated. Greater fill thicknesses might be possible but would require detailed investigations from settlement and stability perspectives.

Treated waste residues could be placed to heights of 15 m above existing ground surface at 3:1 side slopes without significant geotechnical stability concerns. In view of the presence of the weaker stratum noted above, settlement aspects will require a detailed analysis.

The allowable bearing pressure is generally adequate for light-weight structures with shallow strip or pad footings. As a guide, an allowable bearing pressure of 300 kPa can be adopted for footings founded in the upper 1.5 m of the Halton Till. For footings founded in the weaker stratum below the desiccated crust, the allowable bearing pressure is lower, possibly about 150 kPa. Settlement of structures with properly designed footings should not exceed tolerable limits.

For heavy structures, it will likely be necessary to transfer loads to the 'lower till and interbedded sand' unit or to bedrock in order to obtain adequate bearing pressure.

In general, subsoils on this site have good handling and workability characteristics except in wet weather. Trafficability is also good except in wet conditions where problems related to traction and the tracking of 'mud' are likely.

6.0 SUMMARY

Site LF-4N is located within the corporate limits of the Town of Milton about 2 km southeast of the nearest developed area. The site is underlain by Queenston shale and the site is traversed by an east-west trending bedrock valley. Overburden thicknesses are greatest over the valley and range from 15 to 40 m on the site. The overburden is comprised of up to three lower tills, associated granular deposits and the surficial Halton Till. Granular deposits occur throughout the overburden but are most frequently associated with the contacts of the 'lower till and interbedded sand' unit with the Halton Till and with the bedrock. Granular deposits are thickest along the axis of the bedrock valley.

The Halton Till comprises the confining layer. Fracturing in the surficial portion of the Halton Till is considered to be limited to about 5 m, however the heavily fractured zone is less than 2 m thick. Ground water flow in the fractured zone is primarily lateral and ground water flow rates are in the range of 100 m per year. Vertical ground water movement occurs

at very slow rates through the confining layer. Calculations based on average values for hydraulic parameters indicate that the unfractured portion of the confining layer is the dominant hydrogeologic unit with estimated rates of flow in the range of 0.02 m per year. Upward gradients may exist over portions of the site.

Dug/bored wells, drilled wells, cisterns, and ponds are sources of water supply in the study area. Dug/bored wells are most common and about half obtain their water from the bedrock. Most drilled wells obtain their water from the upper part of the shale and from granular deposits. Well yields are generally low but sufficient for domestic needs and cisterns and ponds are sometimes used to supplement water supplies. Water quality is hard but is usually acceptable for drinking although deeper bedrock wells sometimes encounter salty, mineralized, or sulphurous water.

Potential contaminant pathways for offsite movement include natural ground water flow systems and man-made conduits through the confining layer. Man-made conduits include dug/bored wells, drilled wells, and boreholes.

Geotechnical conditions at the site appear to pose no serious problems. The Halton Till has an upper desiccated crust which is relatively thick. Stiff to very stiff and very dense lower tills underlie the Halton Till. Temporary excavations can be safely extended to 15 m at 2:1 side slopes, however, due to the potential for heave, excavations should not be terminated within 4 m of saturated sand seams. Where saturated granular deposits are encountered, ground water control would likely be necessary. Treated waste residues may

be placed to thicknesses of about 1.5 times cell depth below grade. Subsoils would be stable for treated waste residues placed at surface (at 3:1 slopes) to heights of 15 m. Adequate bearing capacity is generally available for building foundations, although loads should be transferred to the very dense lower tills or to bedrock for heavy structures.

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8.0 SUPPORTING INFORMATION

8.1 SUMMARY OF WATER WELL DATA (TABLE 4)

8.2 SUMMARY OF SITE INTERVIEW (WALK AND TALK) DATA (TABLE 5)

8.3 BOREHOLE LOGS

8.4 SUPPORTING CALCULATIONS AND METHODS

8.5 GLOSSARY OF SELECTED TERMS

8.6 DETAILED FIELD METHODS

8.1 SUMMARY OF WATER WELL DATA

Copies of original Water Well Records obtained from the Ontario Ministry of the Environment (MOE) were used for the following data summary and are on file.

Water well locations are shown in Figure 4 (in map pocket).

Measurements, dimensions and quantities on the Water Well Records are in Imperial units but are presented in metric units in the summary.

Water well locations (Figure 4) were plotted on 1:10 000 scale working maps for this project and elevations were re-estimated based on the more accurate contours on these maps. Well elevations are above sea level (A.S.L.) and are estimated to the nearest metre.

Well records are arranged in numerical order.

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-4N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS MATERIALS DESCRIPTION FROM (m)	TO (m)	
577	BARNES, C CON 5 NS, LOT 4 CITY OF BURLINGTON (PREV. NELSON TWP.)	180	MAY 1962	76.2	15.8	FRESH	15.1	7.6	--	0.1	DOMESTIC	0.0 3.7 13.7	3.7 13.7 15.8	BROWN SOIL REDDISH CLAY RED SHALE
578	CAMPBELL, E CON 5 NS, LOT 4 CITY OF BURLINGTON (PREV. NELSON TWP.)	178	MAY 1962	76.2	9.8	FRESH	10.1	4.6	--	<0.1	DOMESTIC	0.0 3.7 7.6	3.7 7.6 9.8	BROWN SOIL RED CLAY RED SHALE
581	PINKNEY, JAMES CON 5 NS, LOT 6 CITY OF BURLINGTON (PREV. NELSON TWP.)	180	NOV 1966	12.7	19.5	FRESH	18.9	0.9	18.3	0.3	DOMESTIC	0.0 1.2 12.8 18.6	1.2 12.8 18.6 19.8	BLACK LOAM BROWN CLAY HARD GREY CLAY RED SHALE
582	KENNY, FRED CON 5 NS, LOT 6 CITY OF BURLINGTON (PREV. NELSON TWP.)	185	NOV 1966	12.7	34.1	FRESH	22.9	11.3	32.6	0.3	DOMESTIC	0.0 0.1 17.4 22.9	0.1 17.4 22.9 34.4	BLACK LOAM BROWN CLAY GRAVEL, SILT RED SHALE
683	BAUDEN, BRUCE CON 6 NS, LOT 5 CITY OF BURLINGTON (PREV. NELSON TWP.)	182	JUN 1958	15.9	10.7	FRESH	11.3	1.2	7.9	0.3	DOMESTIC	0.0 0.8 3.7 8.5 10.7 11.0	0.8 3.7 8.5 10.7 11.0 12.2	BROWN TOPSOIL BROWN CLAY BLUE CLAY BLUE CLAY, GRAVEL GRAVEL, COARSE SAND RED SHALE
684	LAING, A CON 6 NS, LOT 6 CITY OF BURLINGTON (PREV. NELSON TWP.)	183	OCT 1954	15.9	21	FRESH	21.0	0.6	--	2.3	DOMESTIC	0.0 2.4 15.2	2.4 15.2 21.0	CLAY BLUE CLAY SAND AND FINE GRAVEL

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-4N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	TO (m)	MATERIALS DESCRIPTION
605	SKAITH, ALAN CON 6 NS, LOT 10 CITY OF BURLINGTON (PREV. NELSON TWP.)	208	NOV 1962	15.2	16.8	FRESH	11.6	3.0	16.8	0.1	DOMESTIC	0.0	5.5	BROWN CLAY
												5.5	9.8	GREY CLAY
												9.8	11.3	RED CLAY
												11.3	20.4	RED SHALE
606	TASKER, MURRAY CON 6 NS, LOT 10 CITY OF BURLINGTON (PREV. NELSON TWP.)	213	OCT 1966	15.9	12.2	FRESH	7.6	6.1	14.3	0.2	DOMESTIC	0.0	0.6	TOPSOIL
												0.6	6.1	RED CLAY
												6.1	14.3	RED SHALE
628	HALL, W CON 7 NS, LOT 5 TOWN OF MILTON (PREV. NELSON TWP.)	181	AUG 1955	15.9	22.9	SALTY	17.7 (PULLED)	1.5	22.9	0.1	ABANDONED	0.0	12.2	SAND, CLAY
												12.2	17.1	CLAY, GRAVEL
												17.1	22.9	RED SHALE
629	HALL, W CON 7 NS, LOT 5 TOWN OF MILTON (PREV. NELSON TWP.)	181	AUG 1955	15.9	18.3	FRESH	18.3	7.6	17.7	--	DOMESTIC	0.0	13.7	SAND AND CLAY
												13.7	17.1	CLAY, GRAVEL
												17.1	30.1	RED SHALE
630	BLAKELOCK, L CON 7 NS, LOT 6 TOWN OF MILTON (PREV. NELSON TWP.)	182	JUL 1964	15.9	7 13.7	FRESH	18.9	2.1	11.3	0.8	DOMESTIC	0.0	4.3	BUFF CLAY
												4.3	7.0	GREY CLAY
												7.0	7.6	QUICKSAND, GREY CLAY
												7.6	15.8	REDDISH CLAY, GRAVEL
												15.8	17.4	FINE SAND, CLAY
												17.4	18.6	FINE GRAVEL, CLAY
												18.6	18.9	COARSE GRAVEL, CLAY
631	MCLAUCHLAN CON 7 NS, LOT 6 TOWN OF MILTON (PREV. NELSON TWP.)	181	MAR 1965	15.9	14.6	FRESH	--	1.8	17.7	1.1	DOMESTIC	0.0	4.6	BUFF CLAY
												4.6	13.4	GREY CLAY
												13.4	14.6	GREY CLAY AND SAND
												14.6	18.3	CLAY AND GRAVEL

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-4N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS MATERIALS DESCRIPTION FROM (m)	TO (m)	
632	PROUDFOOT, R.M. CON 7 NS, LOT 8 TOWN OF MILTON (PREV. NELSON TWP.)	187	MAR 1955	15.9	19.8	FRESH	15.9	2.4	--	--	DOMESTIC	0.0 15.2	15.2 20.4	CLAY RED SHALE
633	NEWELL, A.R. CON 7 NS, LOT 9 TOWN OF MILTON (PREV. NELSON TWP.)	188	OCT 1955	15.9	20.1 21.9	MINERAL	18.0	2.1	22.9	0.2	STOCK DOMESTIC	0.0 4.6 16.8	4.6 16.8 22.9	CLAY GRAVEL, CLAY RED SHALE
634	MCNALLY, GEO CON 7 NS, LOT 10 TOWN OF MILTON (PREV. NELSON TWP.)	191	MAY 1967	15.9	19.5	FRESH	6.1	1.2	17.7	--	DOMESTIC	0.0 4.3	4.3 20.7	BROWN CLAY RED SHALE
635	MCNALLY, GEO CON 7 NS, LOT 10 TOWN OF MILTON (PREV. NELSON TWP.)	191	JUN 1967	15.9	19.8	FRESH	6.5	1.2	17.4	0.1	DOMESTIC	0.0 4.3	4.3 20.4	BROWN CLAY RED SHALE
637	FAY, JAMIE CON 7 NS, LOT 11 TOWN OF MILTON (PREV. NELSON TWP.)	198	FEB 1966	15.9	21.3	SALTY	6.1	7.6	18.3	2.3	DOMESTIC	0.0 6.1	6.1 22.3	PREDUG RED SHALE
2460	KOLLER, H CON 1 NS, LOT 3 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	180	AUG 1951	15.2	18.9	FRESH	12.2	6.1	--	--	STOCK DOMESTIC	0.0 12.2	12.2 18.9	BLUE CLAY RED ROCK
2461	MCFADDEN, WILLIAM CON 1 NS, LOT 5 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	181	MAR 1960	76.2	15.8	FRESH	15.8	--	--	--	DOMESTIC	0.0 3.7 15.2	3.7 15.2 15.8	BROWN CLAY GREY CLAY COARSE GRAVEL

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-4N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	TO (m)	MATERIALS DESCRIPTION
2462	LAWRENCE, D CON 1 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	187	JAN 1955	15.9	25.6	MINERAL	18.3 (PULLED)	5.5	--	--	ABANDONED	0.0 6.7 18.3	6.7 18.3 25.9	BLUE CLAY CLAY, SAND, GRAVEL RED SHALE
2463	LAWRENCE, D CON 1 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	187	JAN 1955	15.9	21.9	MINERAL	19.5	5.5	--	0.1	DOMESTIC	0.0 7.3 18.9	7.3 18.9 22.3	BLUE CLAY CLAY, SAND AND STONE RED SHALE
2464	FEW, DONALD CON 1 NS, LOT 8 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	195	JUL 1962	15.9	7.6 12.8 13.7	FRESH	5.9	3.7	6.7	0.1	DOMESTIC	0.0 1.5 2.7	1.5 2.7 15.8	CLAY STONEY CLAY RED SHALE
2476	WATT, MARTIN CON 2 NS, LOT 4 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	183	AUG 1964	15.2	21.6	FRESH	22.9	8.2	13.7	0.8	DOMESTIC	0.0 2.1 17.1 20.7	2.1 17.1 20.7 22.9	GREY CLAY REDDISH CLAY GREY CLAY GREY CLAY, GRAVEL
2479	TASKER, THORTON CON 2 NS, LOT 5 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	185	AUG 1962	76.2	12.8	FRESH	17.4	12.2	--	0.1	STOCK DOMESTIC	0.0 6.1 12.8 13.7	6.1 12.8 13.7 17.4	BROWN SANDY CLAY REDDISH BLUE CLAY BLUE CLAY WITH LAYERS OF SAND BLUE CLAY AND BOULDERS
2482	LAWRENCE, KEN CON 2 NS, LOT 8 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	196	MAY 1954	76.2	16.8	FRESH	17.1	4.6	--	0.3	DOMESTIC	0.0 4.6	4.6 16.8	BROWN SOIL RED SHALE
2774	NEWELL, GEORGE CON 7 NS, LOT 11 TOWN OF MILTON (PREV. NELSON TWP.)	200	MAR 1968	76.2	8.2	FRESH	8.5	3.7	--	--	DOMESTIC	0.0 5.2	5.2 8.2	BROWN SOIL RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-4N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS MATERIALS DESCRIPTION FROM (m)	TO (m)	
2847	ODEHNAL, F CON 6 NS, LOT 11 TOWN OF MILTON (PREV. NELSON TWP.)	210	APR 1968	76.2	11.6	FRESH	13.7	10.7	--	--	DOMESTIC	0.0	3.0	BROWN CLAY
												3.0	11.6	BLUE CLAY
												11.6	13.7	RED SHALE
2900	HALL, W CON 7 NS, LOT 5 TOWN OF MILTON (PREV. NELSON TWP.)	181	DEC 1968	76.2	5.5	FRESH	10.1	2.4	--	--	DOMESTIC	0.0	0.9	TOPSOIL
												0.9	1.5	GREY CLAY
												1.5	9.8	BROWN CLAY
3065	BEDER, R. A. CON 7 NS, LOT 9 TOWN OF MILTON (PREV. NELSON TWP.)	188	APR 1969	76.2	10.1 14	FRESH SALTY	14.6	1.2	--	--	DOMESTIC	0.0	0.3	TOPSOIL
												0.3	10.7	BROWN AND GREY CLAY
												10.7	14.0	GREY SILT
3183	SIMON, F CON 6 NS, LOT 6 CITY OF BURLINGTON (PREV. NELSON TWP.)	185	JUN 1969	76.2	9.1	FRESH	18.4	17.7	1.2	--	DOMESTIC	0.0	0.6	TOPSOIL
												0.6	17.4	BROWN CLAY, STONES
												17.4	17.7	GREY SAND AND GRAVEL
3195	WALLACE, JOHN CON 6 NS, LOT 5 CITY OF BURLINGTON (PREV. NELSON TWP.)	183	JUL 1969	76.2	7 10.4	FRESH	10.1	1.2	10.7	--	DOMESTIC	0.0	0.6	BLACK TOPSOIL
												0.6	6.7	BROWN CLAY, STONES, HARD
												6.7	10.7	BROWN SAND, GRAVEL, HARD PACKED
3198	ROGERS, J CON 6 NS, LOT 4 CITY OF BURLINGTON (PREV. NELSON TWP.)	185	SEP 1964	76.2	12.2	FRESH	13.1	2.4	12.8	--	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	4.0	BROWN CLAY, HARD
												4.0	7.9	BLUE CLAY, HARD
												7.9	11.6	GREY CLAY, STONES AND BOULDERS, HARD
												11.6	12.8	BROWN SAND, GRAVEL
												12.8		RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-4N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	TO (m)	MATERIALS DESCRIPTION
3202	FREEMAN, M.R. CON 7 NS, LOT 7 TOWN OF MILTON (PREV. NELSON TWP.)	184	SEP 1969	76.2	16.8	FRESH	17.4	3.0	17.4	--	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	3.7	BROWN CLAY, HARD
												3.7	15.2	GREY CLAY, STONES, HARD
												15.2	17.4	BROWN CLAY WITH SAND LAYERS AND SILT, SOFT
3231	RYAN, JACK CON 6 NS, LOT 6 CITY OF BURLINGTON (PREV. NELSON TWP.)	185	JUL 1969	15.9	16.8	FRESH	--	0.9	20.7	0.3	STOCK	0.0	9.1	PREDUG
												9.1	16.8	GREY CLAY
												16.8	18.3	GREY SAND
												18.3	22.3	GREY CLAY, GRAVEL
												22.3	22.5	RED SHALE
3253	GIDDINGS, KEN CON 6 NS, LOT 6 CITY OF BURLINGTON (PREV. NELSON TWP.)	181	JUN 1969	10.5	21	FRESH	15.2	FLW	--	0.8	DOMESTIC	0.0	15.2	RED CLAY
												15.2	18.3	RED SHALE
												18.3	21.0	BLUE SHALE
3312	DENZIL, L CON 1 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	187	FEB 1970	76.2	4.9 7.6	FRESH	12.5	3.0	12.2	--	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	4.9	BROWN CLAY, HARD
												4.9	6.4	GREY CLAY, STONES, HARD
												6.4	12.5	BROWN SAND, GRAVEL, SILT, HARD PACKED
3463	LUEDERS, G CON 1 NS, LOT 3 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	180	JUN 1970	76.2	11.3	FRESH	15.8	9.8	15.2	--	STOCK	0.0	0.3	BLACK TOPSOIL
												0.3	4.9	BROWN CLAY, HARD
												4.9	6.7	GREY CLAY, STONES, HARD
												6.7	11.6	BROWN CLAY, STONES, HARD
												11.6	15.8	RED SHALE, HARD
3533	LIMESTONE HALL FARMS CON 6 NS, LOT 10 CITY OF BURLINGTON (PREV. NELSON TWP.)	199	AUG 1970	76.2	6.1	FRESH	8.8	6.1	--	0.8	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	4.0	BROWN CLAY
												4.0	5.5	GREY CLAY, HARD AND DRY
												5.5	5.8	GREY GRAVEL, SAND, STONES
												5.8	6.4	GREY GRAVEL
												6.4	8.8	BROWN SAND, CLAY

TABLE 4, SUMMARY OF WATER WELL DATA

Site : LF-4N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS MATERIALS DESCRIPTION FROM (m)	TO (m)	
3536	PARKS, VIC CON 6 NS, LOT 11 TOWN OF MILTON (PREV. NELSON TWP.)	221	JUL 1976	76.2	11.3	--	12.5	3.0	--	<0.1	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	5.0	BROWN CLAY WITH GREY LAYERS
												5.0	9.1	BROWN CLAY, SAND, STONES
												9.1	12.5	RED SHALE
3742	DAWSON, HAROLD CON 6 NS, LOT 3 CITY OF BURLINGTON (PREV. NELSON TWP.)	178	DEC 1971	76.2	14	FRESH	16.5	6.1	16.5	--	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	4.3	BROWN CLAY, DENSE
												4.3	7.3	GREY CLAY, DENSE
												7.3	9.1	BROWN CLAY, STONES, DENSE
												9.1	16.5	RED SHALE, GREEN SHALE, HARD
3755	COLEMAN CON 5 NS, LOT 10 CITY OF BURLINGTON (PREV. NELSON TWP.)	207	MAY 1971	76.2	9.1	FRESH	12.5	8.8	9.1	1.5	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	5.5	BROWN CLAY, STONES, HARD PACKED
												5.5	7.9	BROWN SAND, GRAVEL, CLAY, PACKED
												7.9	8.5	RED SAND, GRAVEL, DENSE
												8.5	12.5	GREY GRAVEL, STONES, FIRST DENSE THEN LOOSE
3912	GROTJAHN, HANNS CON 5 NS, LOT 5 CITY OF BURLINGTON (PREV. NELSON TWP.)	181	MAY 1972	91.4	5.2 15.5	FRESH FRESH	18.3	9.4	15.2	0.7	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	1.2	BROWNISH RED SUBSOIL
												1.2	5.2	BROWN CLAY, VERY SOLID
												5.2	5.5	GREY GRAVEL
												5.5	9.8	GREY CLAY, STONES
												9.8	15.5	BROWN CLAY, STONES
												15.5	16.8	GREY SAND LAYER AND SILT
												16.8	18.3	GREY CLAY, STONES, VERY SOLID
4074	NURSE WILLIAM CON 1 NS, LOT 3 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	181	FEB 1973	76.2	13.4	FRESH	14.0	1.8	14.0	0.3	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	3.7	BROWN CLAY, STONES, SOFT PARTLY AND HARD PACKED
												3.7	4.9	GREY CLAY, STONES, PACKED
												4.9	7.6	BROWN CLAY, RED CLAY, SAND LAYER PACKED
												7.6	9.4	GREY CLAY, HARD PACKED
												9.4	12.2	BROWN CLAY, STONES, HARD PACKED
												12.2	13.4	BLUE CLAY, SOFT
												13.4	13.7	GREY GRAVEL, COARSE SAND
												13.7	14.0	BROWN CLAY, STONES, HARD

TABLE 4, SUMMARY OF WATER WELL DATA

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	DRILLERS MATERIALS DESCRIPTION
4158	IRWIN, W CON 5 NS, LOT 5 CITY OF BURLINGTON (PREV. NELSON TWP.)	181	JUN 1973	76.2	7.6	FRESH	14.8	4.6	9.8	0.6	DOMESTIC	0.0 0.6 7.6 7.9	0.6 7.6 7.9 10.7	BROWN TOPSOIL RED CLAY BROWN SAND REDDISH CLAY
4273	MYERS, JOHN CON 6 NS, LOT 4 CITY OF BURLINGTON (PREV. NELSON TWP.)	182	JUL 1972	91.4	8.8 15.8	FRESH FRESH	16.2	7.3	10.4	0.9	STOCK DOMESTIC	0.0 0.2 5.8	0.2 5.8 16.0	BROWN TOPSOIL BROWN CLAY, STONES GREY CLAY AND STONES WITH SAND SEAMS
4370	CAMPBELL, LARRY CON 5 NS, LOT 5 CITY OF BURLINGTON (PREV. NELSON TWP.)	180	OCT 1973	76.2	7	FRESH	9.4	3.7	5.5	0.5	DOMESTIC	0.0 0.3 4.0 6.7 7.0	0.3 4.0 6.7 7.0 9.4	BROWN TOPSOIL BROWN CLAY GREY CLAY, SOFT BLACK COARSE SAND, SATURATED GREY CLAY, STONES, GREY SAND HARD PACKED
4409	FINELLI CONST. CON 6 NS, LOT 6 CITY OF BURLINGTON (PREV. NELSON TWP.)	181	APR 1974	15.9	16.2 17.4	FRESH FRESH	20.1	FLW	17.7	0.8	DOMESTIC	0.0 5.5 16.2 17.4 18.6	5.5 16.2 17.4 18.6 20.1	BROWN CLAY GREY CLAY GREY SAND, FINE GRAVEL GREY CLAY, GRAVEL, SMALL STONES RED CLAY, GRAVEL
4458	RYAN CON 6 NS, LOT 6 CITY OF BURLINGTON (PREV. NELSON TWP.)	185	OCT 1973	76.2	13.4	FRESH	14.0	FLW	3.0	1.1	DOMESTIC	0.0 0.3 7.3 8.7 13.4	0.3 7.3 8.7 13.4 14.0	BROWN TOPSOIL BROWN CLAY, STONES, HARD PACKED BROWN CLAY, SOFT BROWN CLAY, STONES, HARD PACKED BLACK COARSE SAND, GRAVEL
4459	PYNKOSKI, H CON 6 NS, LOT 6 CITY OF BURLINGTON (PREV. NELSON TWP.)	184	AUG 1973	76.2	16.8	FRESH	17.1	7.6	10.7	0.5	DOMESTIC	0.0 0.3 1.2 12.2 15.5 16.8	0.3 1.2 12.2 15.5 16.8 17.1	BROWN TOPSOIL GREY CLAY BROWN CLAY, STONES, PACKED BROWN CLAY, SAND, HARD PACKED BROWN SAND, LOOSE GREY CLAY

TABLE 4, SUMMARY OF WATER WELL DATA

Site : LE-4N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	TO (m)	MATERIALS DESCRIPTION
4481	RYAN, J CON 6 NS, LOT 6 CITY OF BURLINGTON (PREV. NELSON TWP.)	184	FEB 1974	76.2	15.8	FRESH	16.8	7.6	10.7	0.5	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	6.1	BROWN CLAY, STONES, VERY HARD
												6.1	9.1	GREY CLAY, BLUE CLAY, SOFT
												9.1	15.8	BROWN CLAY, SHALE, GREY CLAY, SILT SAND
												15.8	16.5	BROWN SAND
												16.5	16.8	BROWN CLAY, SAND, HARD PACKED
4491	CAMPBELL, EDGAR CON 5 NS, LOT 4 CITY OF BURLINGTON (PREV. NELSON TWP.)	175	JUN 1964	76.2	7 13.4	FRESH FRESH	14.0	6.4	10.1	0.5	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	1.2	GREY CLAY, BROWN CLAY
												1.2	5.2	BROWN & RED CLAY, STONES, HARD PACKED
												5.2	5.5	GREY CLAY, BLUE CLAY, SOFT
												5.5	5.8	BROWN COARSE SAND
												5.8	6.4	BROWN CLAY, PACKED
												6.4	6.7	BROWN SAND, MOIST
												6.7	7.0	BROWN CLAY, LOOSE
												7.0	8.5	GREY CLAY, STONES, SILT, HARD PACKED
												8.5	9.8	GREY STONES, BOULDERS, CLAY VERY HARD PACKED
												9.8	14.0	RED SHALE, GREEN SHALE, HARD
4587	JOHNSON, BOB CON 7 NS, LOT 3 TOWN OF MILTON (PREV. NELSON TWP.)	180	JUL 1974	91.4	2.4 6.1	FRESH FRESH	9.1	--	--	--	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	1.2	BROWN CLAY, STONES
												1.2	3.7	GREY CLAY
												3.7	9.1	RED SHALE
5813	SAUA COMPANY LTD. CON 1 NS, LOT 8 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	196	APR 1975	16.8	14	FRESH	15.5	2.4	10.4	0.9	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	3.7	BROWN CLAY
												3.7	6.1	GREY CLAY, STONES
												6.1	15.5	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: LF-4N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS MATERIALS DESCRIPTION FROM (m)	TO (m)	
5144	GAETON, A CON 7 NS, LOT 8 TOWN OF MILTON (PREV. NELSON TWP.)	183	APR 1977	76.2	12.2 18.9	FRESH FRESH	--	9.8	14.3	1.1	DOMESTIC	0.0 0.3 3.0 4.9 5.8 6.7 11.3 12.2 13.1 15.2 18.9	0.3 3.0 4.9 5.8 6.7 11.3 12.2 13.1 15.2 18.9 19.2	TOPSOIL BROWN CLAY, PACKED GREY CLAY, HARD PACKED BLUE CLAY, SOFT BROWN SAND, SOME PACKED GREY CLAY, STONES BLUE CLAY, SOFT GREY SAND, STONES, SOME WATER BROWN CLAY, HARD PACKED GREY CLAY, LAYERED GRAVEL, SAND
5147	HESS/DRUMIAK CON 7 NS, LOT 8 TOWN OF MILTON (PREV. NELSON TWP.)	183	AUG 1977	76.2	11.6 20.1 21.6	FRESH FRESH FRESH	--	6.0	14.6	1.1	DOMESTIC	0.0 0.3 0.9 10.4 11.6 13.7 21.6	0.3 0.9 10.4 11.6 13.7 21.6 22.3	TOPSOIL BROWN CLAY, SAND GREY, BROWN & BLUE CLAY, PACKED BROWN CLAY, SILT, STONES, SOFT GREY CLAY, BROWN CLAY BROWN SAND, HARD PACKED GREY GRAVEL, SAND
5149	SNOW, E CON 7 NS, LOT 4 TOWN OF MILTON (PREV. NELSON TWP.)	181	OCT 1977	76.2	7.9 9.8 11.6	FRESH FRESH FRESH	12.2	2.1	11.9	1.1	DOMESTIC	0.3 1.2 6.1 7.9	1.2 6.1 7.9 11.9	BROWN CLAY, HARD PACKED GREY CLAY, BROWN SILT, SOFT BROWN CLAY, STONES, HARD RED SHALE, SOFT TO 9.7m, HARD BELOW 9.7m
5376	SWETMAN, F CON 6 NS, LOT 5 CITY OF BURLINGTON (PREV. NELSON TWP.)	181	JUL 1979	15.5	11.6	FRESH	--	1.2	7.3	0.3	DOMESTIC			WELL CLEAN OUT, REMOVED SILT AND FINE SAND, BROWN AND BLACK
5377	SWETMAN, F CON 6 NS, LOT 5 CITY OF BURLINGTON (PREV. NELSON TWP.)	181	JUL 1979	76.2	5.5	FRESH	10.1	4.9	--	--	DOMESTIC	0.0 1.2 5.5 5.8 8.2 8.8 12.2	1.2 5.5 5.8 8.2 8.8 12.2 13.7	BROWN CLAY, SAND, SOFT GREY CLAY, STONES, HARD GREY SILT, SOFT GREY CLAY, STONES, HARD GREY CLAY, SAND, SOFT GREY CLAY, STONES, HARD RED SHALE, LAYERED, SOFT

TABLE 4, SUMMARY OF WATER WELL DATA

Site : LF-4N

Sheet 11 of 11

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	TO (m)	MATERIALS DESCRIPTION
5399	ANDERSON, M CON 7 NS, LOT 6 CON NS 7, LOT 6 (PREV. NELSON TWP.)	183	SEP 1979	76.2	9.8	FRESH	13.4	9.8	--	--	DOMESTIC	0.0	3.7	BROWN CLAY, STONES, HARD (TILL)
												3.7	9.8	BROWN CLAY, STONES , FIRM
												9.8	9.9	BROWN SAND, SILT, SOFT
												9.9	14.3	BROWN CLAY, STONES, FIRM
												14.3	14.6	RED SHALE, SOFT
5428	CAMPBELL CITY OF BURLINGTON CON NS 5, LOT 4 (PREV. NELSON TWP.)	163	OCT 1978	76.2	4.3	FRESH	6.7	7.3	--	--	DOMESTIC	0.0	0.3	BROWN TOPSOIL
					8.8	FRESH					STOCK	0.3	4.0	BROWN CLAY, STONES
					11.6	FRESH						4.0	4.6	RED SHALE, HARD
												4.6	12.1	RED SHALE, GREEN SHALE, VERY HARD
5663	POMPA, B CON 1 NS, LOT 3 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	180	JUN 1980	76.2	10.7	FRESH	11.6	1.2	4.6	0.8	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	5.5	BROWN CLAY, PACKED
												5.5	6.1	BLUE CLAY, SOFT
												6.1	10.7	RED CLAY, STONES, PACKED
												10.7	11.6	BROWN SAND, STONES, LOOSE
5687	LAWRENCE, K CON 2 NS, LOT 8 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	197	JUL 1980	76.2	4	FRESH	7.3	0.3	5.8	0.6	DOMESTIC	0.0	0.3	BROWN TOPSOIL
					7.6	FRESH						0.3	3.0	BROWN CLAY, RED CLAY
												3.0	9.8	RED SHALE, GREEN SHALE, HARD
5812	KOVACHIK, P CON NS 6, LOT 3 CITY OF BURLINGTON (PREV NELSON TWP.)	187	APR 1973	76.2	6.4	FRESH	9.4	0.3	6.4	1.1	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	4.3	BROWN CLAY, STONES, SOFT
												4.3	4.6	GREY CLAY, SOFT
												4.6	5.2	BROWN CLAY, HARD
												5.2	9.4	GREY GRAVEL, STONES, SAND, VERY HARD
5823	VERRES, G CON 1 NS, LOT 7 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	193	OCT 1975	76.2	0.3	FRESH	4.9	3.0	6.1	1.1	DOMESTIC	0.0	0.3	BROWN TOPSOIL
					4.9	FRESH						0.3	1.8	BROWN CLAY, STONES, PACKED
												1.8	6.1	RED SHALE, GREEN SHALE, SOFTER AT 4.6 m THEN VERY HARD
5825	AGOSANO, J CON 1 NS, LOT 6 TOWN OF MILTON (PREV. TRAFLAGAR TWP.)	188	JUL 1972	76.2	10.4	FRESH	9.8	3.4	10.4	1.1	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	9.1	BROWN CLAY, RED CLAY, SOME GREY, SOME SANDY LAYERS BUT MAINLY STONES AND BOULDERS
												9.1	10.4	RED SHALE, GREEN SHALE, VERY HARD

8.2 SUMMARY OF SITE INTERVIEW (WALK AND TALK) DATA

Water use data from Ecologistics Limited's field interview (Walk and Talk) forms is presented in Figure 8 (in map pocket). Water use data were collected from onsite and adjacent properties. A copy of the water resources form is included at the end of this section.

Water use data is augmented with information collected by Gartner Lee Associates Limited staff during discussions with local interest groups and individuals.

The results of water well surveys completed by Gartner Lee Associates Limited in 1976 and by Morrison Beatty Limited in 1984 are also incorporated in the summary of site interview data.

Deeper drilled wells are considered to terminate in bedrock where supporting evidence is available.

Although most of the information was provided in Imperial units, it has been converted to metric units for uniformity with the remainder of the report.

Interview numbers are related to identifications assigned by Ecologistics Limited during the collection of these data. Copies of the interview forms are on file.

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LF-4N Sheet 1 of 20

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s	Cistern	Remarks
1	Mr. and Mrs. H. Vanzowl	8 Town of Milton (formerly Nelson Twp.)	7NS	125-2	2			Drilled well (MOE well 632) - 18.3 m (60 ft.) deep - domestic use - water quality sulphurous, iron content and hard Drilled well (no MOE record) - 12.2 m (40 ft.) deep - domestic use Pond on property
2	Mr. J. Stutt	7 Town of Milton (formerly Nelson Twp.)	1NS	244-2	✓	2		Drilled well (no MOE record) - 35.5 m (110 ft.) deep - poor water quality - not used Dug/Bored well (no MOE record) - domestic use - 13.4 m (44 ft.) deep Dug/Bored well (No MOE record) - not used - water quality not good - sulphurous, salty

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
3	Mr. John Reid (Tenant)	7 Town of (formerly Twp.)	7 NS Milton Nelson	516		✓		Dug/Bored well (No MOE record) - water quality sulphurous - not used
3	Mr. Norm Mogil (owner)	7 Town of (formerly Twp.)	7NS Milton Nelson	54-2				Drinking water not particularly good - no other water use information.
3	Mr. Paul Easterbrook (tenant - resident)	7 Town of (formerly Twp.)	7NS Milton Nelson	GLAL Field Visit	✓	✓	✓	Dug/Bored Well (No MOE record) - 10.7 m (35 ft.) deep - livestock use - water has sulphur smell Drilled well (No MOE record) - abandoned, plugged Cistern in basement Buys water for drinking

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LF-4N Sheet 3 of 20

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
4	Mr. James Johnston	8 Town of Milton (formerly Nelson Twp.)	7NS	31-1		✓		Dug/Bored well (MOE well 5147) - 23.8 m (78 ft.) deep - domestic use - water quality good, no sulphur or iron, water has been tested
5	Mr. Joe DeAngeles (owner)	6 Town of Milton (formerly Nelson Twp.)	7NS	37-1a	✓	✓	✓	Drilled well (No MOE record) - 13.7 m (45 ft.) deep - water quality good, not salty - occasionally runs out of water. Water recovery within short time (GLAL field info.) Dug/Bored well (no MOE record) - 9.1 m (30 ft.) deep - stock use (GLAL field information) Cistern - used for house as backup to well, not used for drinking Pond on property

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LF-4N Sheet 4 of 20

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
5	Mr. Jerry McLaren (resident tenant)	6 Town of Milton (formerly Nelson Twp.)	7NS	764	✓	✓	✓	Drilled well (No MOE record) - domestic use - goes dry in summer Dug/Bored well (No MOE record) - stock use - never goes dry Cistern - domestic use as backup for well Pond 6.1 m (20 ft.) deep
6	Mr. A. Palermo	6 Town of Milton (formerly Trafalgar Twp.)	1NS	123-1	✓		✓	Drilled well (No MOE record) - 18.3 m (60 ft.) deep - water quality good - domestic and stock use - well goes dry with heavy use for 1/2 day, has occurred twice in one year. Cistern - domestic use Pond on property

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LF-4N Sheet 5 of 20

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
7	Mr. J. Snyder	5 Town of Milton (formerly Trafalgar Twp.)	1NS	760				No water use information and no wells on property
8	Mr. Roy Bousfield	10 Town of Milton (formerly Nelson Twp.)	7NS	501-G		2	✓	Dug/Bored well (No MOE record) - domestic and stock use - 2.1-2.4 m (7-8 ft.) deep - water quality salty, very hard - 0.3 L/sec (4.5 gpm) pumping capacity - artesian (spring) Dug/Bored well abandoned and filled in (No MOE record) Cistern - domestic use, wash water - does not go dry Pond, 2.7 m (9 ft.) deep, does not go dry.

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LF-4N Sheet 6 of 20

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
9	Mr. & Mrs. Smith (tenants)	7 Town of Milton (formerly Nelson Twp.)	7NS	296	✓	4		Drilled well (No MOE record) - domestic use - 35.1 m (115 ft.) deep - water quality hard 4 Dug/Bored wells (no MOE record for 3 wells) - one supplies household Wells are 8.2 m (27 ft.) deep - one caved in, one filled in, and one dry Dug/Bored well (MOE well 3202) 17.4 m (57 ft.) deep
10	Robert F. Kowal Instruments Ltd.	6 Town of Milton (formerly Nelson Twp.)	7NS	204				Vacant land - no water use information
11	Ms. J. Peric	5 Town of Milton (formerly Nelson Twp.)	7NS	43-2				No water use on property

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LF-4N Sheet 7 of 20

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
12	Mr. H. C. Reid	8 Town of Milton (formerly Nelson Twp.)	6NS	519		2		Dug/Bored well (No MOE record) - domestic use - 2.7 m (9 ft.) deep - good water quality Dug/Bored well (No MOE record) - stock use - 2.7 m (9 ft.) deep - good water quality
12	Mr. H. C. Reid	9 Town of Milton (formerly Nelson Twp.)	6NS	519		(✓)		Well (No MOE record) - unknown type - flowing well
13	Mr. Donald Sherwood	7 Town of Milton (formerly Nelson Twp.)	6NS	55-2		2 (✓)		Dug/Bored well (No MOE record) - domestic use - 17.4 m (57 ft.) deep - water quality, hard (quality has gone bad due to livestock pollution Dug/Bored well (No MOE record) - domestic use - 8.5 m (28 ft.) deep Well -unknown type (No MOE record) - livestock use - 21.3 m (70 ft.)deep - artesian

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LF-4N Sheet 8 of 20

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
14	Ms. M.B. Kennedy	6 City of Burlington (formerly Nelson Twp.)	6NS	84-1a	✓			Drilled well (MOE well 604) - domestic and stock use - water quality excellent
15	Mr. Lissi c/o Attardo Co. Ltd	6 City of Burlington (formerly Nelson Twp.)	6NS	67-2				No wells, streams or ponds on property
16	Mr. and Mrs. W. Anderson	6 Town of Milton (formerly Nelson Twp.)	7NS	5-2		2	2	Dug/Bored well (no MOE record) - domestic use - 9.1 m (30 ft) deep - water quality hard Dug/Bored well (MOE well 5399) - stock use, 0.3-0.4 L/sec (4-5 gpm) - 15.2 m (50 ft) deep - water quality, high TDS and hard Well - Unknown type (no MOE record) - artesian, abandoned - location unknown (con't)

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
16	Mr. and Mrs. W. Anderson (continued)	6 Town of Milton (formerly Nelson Twp.)	7NS	5-2				Cistern for domestic use - occasionally truck in water Cistern for stock use Pond in centre of race track - water stays fresh through summer
17	Ms. M.E. McLauchlan	6 Town of Milton (formerly Nelson Twp.)	7NS	215-1	✓			Drilled well (MOE well 631) - domestic use - 18.3 m (60 ft) deep - water quality very good, a little iron
18	Mr. and Mrs. D. LeBlanc	6 City of Burlington (formerly Nelson Twp.)	6NS	49-2	✓			Drilled well (MOE well 3253) - domestic and stock use - not very deep - water quality, hard, iron content high - flowing well, never goes dry Pond dries up in July and August is otherwise full of water

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
19	Ms. Bertha Hall	5 Town of Milton (formerly Nelson Twp.)	7NS	78-2	✓	✓		Drilled well (no MOE record) - domestic use - 20.4 m (67 ft) deep - good drinking water - no abundance of water Dug well (no MOE record) - domestic use for hot water - 9.1 m (30 ft) - good drinking water Pond on property Abandoned gas well - location unknown
20	Mr. Earl Snow	4 Town of Milton (formerly Nelson Twp.)	7NS	143-2	✓	(✓)		Drilled well (no MOE record) - domestic and stock use - 24.5 m (77 ft) deep, 15.2 cm (6 in) steel casing - water quality hard with iron - has never gone dry Wells - Unknown type (no MOE records) - a number of old (abandoned) wells on property

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
21	Mr. and Mrs. G. Love (Tenant)	4 Town of (former Twp.)	7NS Milton y Nelson	100-2		✓	✓	Dug/Bored well (no MOE record) - domestic use - 12.2 m (40 ft) deep - water quality soft, not always good to drink - well overflows in spring or when it rains Cistern - domestic use
21	Mr. Stewart Scott	4 Town of (former	7NS Milton y Nelson	609 Twp.)				Pond on property - good for livestock
22	Ms. Myrtle D. Hall	4 Town of (former Twp.)	7NS Milton y Nelson	486-G	✓			Drilled well (no MOE record) - domestic use - 25.9 m (85 ft) deep, 15.2 cm (6 in) diameter casing - water quality, terrible, a lot of minerals Pond on property - good for cattle

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LF-4N Sheet 12 of 20

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
23	Mr. and Mrs. Paul Patrick	8 Town of Milton (formerly Nelson Twp.)	7NS	47-1		✓		Dug/Bored well (MOE well 5144) - domestic use and for watering gardening - 18.3 m (60 ft) deep - water quality soft
24	G. Marshall	4 Town of Milton (formerly Trafalgar Twp.)	1NS	N/A		✓		Dug/Bored well (no MOE record) MORRISON BEATTY LTD. WELL SURVEY
25	Mr. and Mrs. Manuel Da Silva	4 Town of Milton (formerly Trafalgar Twp.)	1NS	467-G		✓		Dug/Bored well (no MOE record) - domestic use - 15.5 m (51 ft) deep - water quality hard - has dried up twice
26	Mr. A. Palermo	6 Town of Milton (formerly Trafalgar Twp.)	1NS			2		Dug/Bored wells (no MOE records) MORRISON BEATTY LTD. WELL SURVEY

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
27	M. Hedges	5 Town of (formerly Trafalgar Twp.)	2NS Milton			2		Dug/Bored well (MOE well 2479) Dug/Bored well (no MOE record) MORRISON BEATTY LTD. WELL SURVEY
28	Van Zwol	8 Town of (formerly Nelson Twp.)	7NS Milton			✓		Dug/Bored well (no MOE record) MORRISON BEATTY LTD. WELL SURVEY - well 4N-10
29	Pettigrew	7 City of (formerly Nelson Twp.)	6NS Burlington			✓		Dug/Bored well (no MOE record) MORRISON BEATTY LTD. WELL SURVEY - well 4N-10

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
30	Waid	5 Town of Milton (formerly Trafalgar Twp.)	1NS			✓		Dug/Bored well (no MOE record) MORRISON BEATTY LTD. WELL SURVEY Pond (GLAL Airphoto Review)
31	Mr. F. Van Wassenaer	3 Town of Milton (formerly Trafalgar Twp.)	1NS	272		2		Dug/Bored well (MOE well 3463) - domestic and stock use - 17.1 m (56 ft) deep - water quality hard Dug/Bored well (no MOE record) - domestic and stock use - water quality hard Two ponds on property
32	GLAL Field Observation	4 Town of Milton (formerly Trafalgar Twp.)	1NS			✓		Dug/Bored well (no MOE record) - abandoned

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
33	Mrs. Beverly Ketelaars	3 Town of Milton (formerly Trafalgar Twp.)	1NS	222-1	✓	✓		Drilled well (no MOE record) - domestic use - 21.3 m (70 ft) deep - water quality hard Dug/Bored well (no MOE record) - domestic use - 15.2-16.8 m (50-55 ft) deep - periodically goes dry Bottled water for drinking
34	Mr. Bill Bousefield	4 Town of Milton (formerly Trafalgar Twp.)	2NS	126-2				No water use information
35	Mr. Lloyd Moore	3 Town of Milton (formerly Trafalgar Twp.)	1NS	781		✓		Dug/Bored well (no MOE record) - domestic use - 15.8 m (52 ft) deep - water quality good

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
36	Mr. and Mrs. Clare Ford	3 Town of Milton (formerly Trafalgar Twp.)	2NS	22-1		✓	✓	Dug/Bored well (no MOE record) - domestic use - 5.2 m (17 ft) deep - water quality good, hard - goes dry during dry periods, once every two years Cistern - domestic use, laundry and toilet
37	Mr. and Mrs. B. Pompa	3 Town of Milton (formerly Trafalgar Twp.)	1NS	51-2		✓		Dug/Bored well (MOE well 5663) - domestic use - 11.6 m (38 ft) deep - water quality hard Two Ponds on property
38	Mr. Walter Chlon	3 Town of Milton (formerly Trafalgar Twp.)	1NS	238-2		✓		Dug/Bored well (no MOE record) - domestic use - 12.8 m (42 ft) deep - water quality hard Pond on property

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LF-4N Sheet 17 of 20

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
39	Mr. and Mrs. Kip Chaput	3 Town of Milton (formerly Trafalgar Twp.)	1NS	15-2		✓		Dug/Bored well (MOE well 4074) - domestic use - 0.8 m (30 in) diameter - water quality good, slightly hard Pond on property
40	Gentex Pharmaceuticals	5 Town of Milton (formerly Trafalgar Twp.)	1NS	37-2				No water use information
41	Mr. P. Szkilniak	6 Town of Milton (formerly Trafalgar Twp.)	2NS	35-2		(✓)		Well - Unknown type (no MOE record) - domestic use - water quality; dirty, bitter alright for animals Pond on property
42	John Reid	7 Town of Milton (formerly Trafalgar Twp.)	7NS	516				No water use on property

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
43	Mrs. Joanne Templeman	4 Town of Milton (formerly Trafalgar Twp.)	1NS	459-G	✓	✓		Drilled well (no MOE record) - 12.6 m (41.5 ft) deep - water quality good, a little hard Dug/Bored well (no MOE record) - domestic use, drinking and cooking - water quality good a little hard
44	Rush	9 Town of Milton (formerly Trafalgar Twp.)	1NS			(✓)		Unknown well type from GLAL 1976 well survey
45	Larouche	9 Town of Milton (formerly Trafalgar Twp.)	1NS			(✓)		Unknown well type from GLAL 1976 well survey
46	Stutt	4 City of Burlington (formerly Nelson Twp.	6NS			(✓)		Unknown well type from GLAL 1976 well survey
47	Kovachik	3 City of Burlington (formerly Nelson Twp.)	6NS			(✓)		Unknown well type from GLAL 1976 well survey

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
48	Kovachik	3 City of Burlington (formerly Nelson Twp.)	6NS			(✓)		Unknown well type from GLAL 1976 well survey
49	Sanford	3 Town of Milton (formerly Nelson Twp.)	7NS			(✓)		Unknown well type from GLAL 1976 well survey
50	Pickering	8 Town of Milton (formerly Trafalgar Twp.)	1NS			(✓)		Unknown well type from GLAL 1976 well survey
51	N/A	10 Town of Milton (formerly Trafalgar Twp.)	1NS			(✓)		Abandoned - Unknown well type from GLAL 1976 well survey
52	Woodley	10 Town of Milton (formerly Trafalgar Twp.)	2NS			(✓)		Unknown well type from GLAL 1976 well survey
53	Whitman	10 Town of Milton (formerly Trafalgar Twp.)	2NS			(✓)		Unknown well type from GLAL 1976 well survey
54	Mr. Ken Wettlaufer	2 Town of Milton (formerly Trafalgar Twp.)	2NS	293				No water use information

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site LF-4N Sheet 20 of 20

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
55	Mr. and Mrs. W.T. Martin	4 Town of (formerly Twp.)	2NS Milton Trafalgar	21-2	✓			Drilled Well (MOE well 2476) - 21.9 m (72 ft.) deep - Water level in well 7.6 m (25 ft.) - used for household - Water quality good, hard.

WATER RESOURCES FORM

Interview Identification Number: _____

PHYSICAL RESOURCES - WATER

We are interested in the water used on this property: where it comes from, its quality, and how much you use.

1. What is this household's source of supply for domestic water? (e.g., drinking, laundry, toilet)

drilled water	☐	Locate on map with symbol Dr-H
dug wells	☐	Locate on map with symbol Du-H
stream water	☐	Locate on map with symbol *SW-H
cistern	☐	Locate on map with symbol *C-H
bottled water	☐	
municipal main	☐	
other, specify		_____

2. What is the water supply for the livestock and irrigation on this property?

drilled wells	☐	Locate on map with symbol Dr-A
dug wells	☐	Locate on map with symbol Du-A
streams or dams	☐	Locate on map with symbol *SW-A
cisterns	☐	
municipal main	☐	
other (e.g., ponds)		_____

3. Are there any streams or ponds on your property?

streams	Yes ☐	No ☐
ponds	Yes ☐	No ☐

4. What can you tell us about the quality of the water

a) you use or drink? (hard, soft, sulphurous, iron, salty, etc.) _____

_____

_____

b) in the streams or ponds? _____

_____

_____

5. Do the wells, cisterns or streams that you use for water supply ever go dry? If so, how often? _____

_____

_____

_____

Interview Identification Number: _____

6. Can you tell us anything about the construction of the wells? (e.g., when they were drilled, depth, type of pump, name of the driller) _____

7. Has any portion of your property been filled or excavated? If so, please show where on the map. (Locate on map with symbol EV.)

8. Do you know where there are any gas or oil wells on your property or the property you farm - in use or abandoned? . Please show their locations on the map with the symbol GW.

9. Please tell us about any problems with flooding in the creeks and streams on your property. Please show locations of the flooded areas on the map. (Locate with symbol FA.) _____

8.3 BOREHOLE LOGS

8.3.1 GARTNER LEE ASSOCIATES LIMITED,
BOREHOLE LOGS, 1984
- Site LF-4N
- Site PI-1N

8.3.2 GARTNER LEE ASSOCIATES LIMITED,
BOREHOLE AND TEST PIT LOGS, 1976-1979

8.3.3 MORRISON BEATTY LIMITED,
BOREHOLE LOGS, 1984

8.3.4 HYDROLOGY CONSULTANTS LIMITED,
BOREHOLE LOGS, 1984

8.3.5 MINISTRY OF TRANSPORTATION AND COMMUNICATIONS,
BOREHOLE LOGS

8.3.1 BOREHOLE LOGS - GARTNER LEE ASSOCIATES LIMITED - 1984

Borehole locations are shown in Figure 4 (in map pocket).

Borehole logs are based on field notes which have been verified by the project geologist following re-examination of samples.

Continuous samples were obtained by advancing a large split tube (8.9 cm x 152 cm) through the hollow stem augers.

Standard penetration tests were performed at 1.5 m intervals and water contents were measured in samples taken from the 'nose-piece' of the standard split spoon sampler.

Textural descriptions are provided for each geologic unit and each deposit is named to indicate its origin.

All material descriptions are based on visual hand-sample examination and no laboratory grain size analyses were performed. Textural descriptions follow a Particle Size Classification System (see Glossary of Selected Terms, Section 8.7).

Borehole elevations are estimated from the 1:10 000 scale base map elevation contours. All elevations are above sea level (ASL) and are estimated to the nearest metre.

The term pebble has been used to describe gravel-sized rock particles within a fine grained soil matrix.

GEOTECHNICAL NOTES AND ABBREVIATIONS

Standard Penetration Resistance 'N' - The number of blows required to advance a standard split spoon sampler 30 cm into the subsoil, driven by means of a 63.5 kg hammer falling freely a distance of 75 cm.

The consistency of cohesive soils and the relative density or denseness of cohesionless soils are described as follows:

Consistency	'N' Blows per 0.3 m	Denseness	'N' Blows per 0.3 m
Very soft	0-2	Very Loose	0-4
Soft	2-4	Loose	4-10
Firm	4-8	Compact	10-30
Stiff	8-15	Dense	30-50
Very Stiff	15-30	Very Dense	> 50
Hard	> 30		

ABBREVIATIONS

WTPL - Wetter than Plastic Limit

DTPL - Drier than Plastic Limit

APL - About Plastic Limit

Wp - Plastic Limit

WL - Liquid Limit

SS - Split Spoon Sample

T - Split Tube Sample

SITE LF-4N

BOREHOLE NO. GL 84-1 (4N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** November 21/84

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 184 m (Approximately) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: very dark greyish brown silt to clayey topsoil, numerous roots								
1.0	CLAYEY SILT TO SILTY CLAY: brown clayey silt to silty clay, heavily weathered and fractured			1	SS	39	16		
	SILT TO CLAYEY SILT TILL: brown silt to clayey silt till, heavily weathered to ±1.5 m, fractures common to 4.2 m, 2 cm fine sand lamina at 5.2 m, very stiff to hard (Halton Till)			2	SS	42	12		
				3	SS	14	13		
	— fine sand 5.6 to 5.7 m, colour change at ±5.7 m								
	— silty fine sand 6.8 to 6.9 m			4	SS	21	13		
				5	SS	18	13		
				6	SS	18	12		
	— indistinctly banded below 10.6 m			7	SS	17	11		
	— 4 cm silt bed at 11.2 m								
	— indistinctly laminated with occasional silt lamina (to 0.5 cm) below 12.2 m			8	SS	15	18		
14.1	— gradational lower contact			9	SS	43	10		
	SILT TILL: reddish brown silt till, with interbedded silt beds to 8 cm, saturated, very dense (Lower Till)								
15.5				10	SS	90	8	→	
	SILT TO FINE SAND: dark grey silt to fine sand, grading from clayey silt at top to gravelly silty fine sand with depth, very dense, saturated			11	SS	79	14	→	
18.4				12	SS	90	8	→	
	SANDY SILT TO SILTY SAND TILL: brown sandy silt to silty sand till, sandy zones below 21 m, gradational lower contact, saturated, very dense (Lower Till)			13	SS	108	7	→	
				14	SS	98	10	→	
				15	T	*	10	* 73/0.15 m →	
23.6									
	CLAYEY SILT: grey clayey silt, massive to well laminated, with red bands, with till-like zones to 2 cm thick			16	SS	85	18	→	
25									

Gartner Lee Associates Limited

BOREHOLE NO. GL 84-1 (4N) (cont'd)

PROJECT NAME: Phase 4A Drilling and Sampling

CLIENT: Ontario Waste Management Corporation — DATE: November 21/84

BOREHOLE TYPE: 108 mm I.D.Hollow Stem Augers, Continuous Sampling — GEOLOGIST: AB/AC

GROUND ELEVATION: 184 m (approximately) — PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
	SILT TO FINE SAND: brown to reddish grey silt to fine sand, with beds of sandy silt till to 0.5 m, sand and till units are gradational, increasing shale content below ±28 m, gradational to shale bedrock, saturated, very dense			17	SS	60	21		
				18	SS	61	20		
				19	SS	64	9		
				20	SS	99	6		
31.5									
	SHALE and SILTSTONE: reddish brown interbedded shale and siltstone, occasional grey-green zone, calcareous, heavily weathered to ±34.0 m (Queenston Formation)			21	SS	*	10	* 80/0.1 m	
34.9									
	Borehole terminated at 34.9 m in shale.								

BOREHOLE NO. GL 84-2 (4N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE November 13/84

BOREHOLE TYPE 108mm I.D.Hollow Stem Augers, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 184 m (approximately) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; WP — WL)
0.2	TOPSOIL: very dark greyish brown clayey silt topsoil, occasional organics								
1.3	SILTY CLAY: dark greyish brown silty clay, occasional small (<1 cm) pebble, carbonate concretions, silt lamina to 0.5 cm between 0.7 and 0.8 m			1	SS	62	11		
	SILT TO CLAYEY SILT TILL: brown silt to clayey silt till, fractures common to ±3.0 m, discoloured fracture 3.4 m, very stiff to hard (Halton Till)			2	SS	42	12		
				3	SS	21	11		
				4	SS	15	13		
	— 2 cm thick lamina of medium sand at 8.0 m			5	SS	16	13		
	— increasing silt and pebble content below ±10 m			6	SS	28	11		
				7	SS	26	10		
				8	SS	26	11		
	— grading to laminated silty clay to silt with occasional till-like layer to 2 cm thick, occasional small (<1 cm) pebble (±13.7 to 15.9 m)			9	SS	24	12		
				10	SS	21	10		
	— return to silt to clayey silt till at ±15.9 m — 7 cm thick layer fine sand at 16.0 m			11	SS	45	9		
18.8	— interbedded silty clay to clayey silt and clayey silt till below ±18.0 m			12	SS	35	25		
	SILT TO SANDY SILT TILL: brown silt to sandy silt till, variable, with sand interbeds to 30 cm and sandy zones, saturated, very dense (Lower Till)			13	SS	103	8		
21.9				14	SS	120	8		
	LAMINATED CLAYEY SILT: dark grey laminated clayey silt, with pebbley and till-like zones, hard			15	SS	88	22		
				16	SS	72	20		

Gartner Lee Associates Limited

BOREHOLE NO. LF 84-2 (4N) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE November 13/84

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 184 m (approximately) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
25.8	LAMINATED CLAYEY SILT: (continued)								
26.5	SANDY SILT TILL: brown sandy silt till, saturated (Lower Till)			17	SS	73	10		
27.8	SILTY SAND: grey silty medium to coarse sand, with gravel, very dense, saturated			18	SS	80	23		
	CLAYEY SILT AND CLAYEY SILT TILL: brown to dark grey clayey silt and clayey silt till, interbedded and gradational in approximately equal proportions, occasional silt lamina to 2 mm, silt layer 31.4 to 31.5 m, hard (Lower Till)			19	SS	88	12		
				20	SS	80	13		
31.8					+T	NA	17		
	SILTY SANDY GRAVEL TO SILTY FINE SAND: grey silty sandy gravel to silty fine sand, variable, till-like in places, saturated				+T	NA	14		
37.1					+T	NA	10		
38.9	SHALE: reddish brown shale, weathered with occasional siltstone zone, occasional grey-green band (Queenston Formation)								
	Borehole terminated at 38.9 m in shale								
50	+ moisture contents taken from (T) split tube samples								

Gartner Lee Associates Limited

BOREHOLE NO GL 84-3 (4N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE November 16/84

BOREHOLE TYPE 108 mm I.D.Hollow Stem Augers, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 188 m (approximately) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: very dark greyish brown silt topsoil, occasional root or straw								
1.0	SILTY CLAY TO CLAYEY SILT: yellowish brown mottled, weathered numerous fractures, rusty 1 cm thick silt lamina at 0.4 m			1	SS	46	21		
	CLAYEY SILT TO SILT TILL: dark greyish brown clayey silt to silt till, numerous shale pebbles, fractures common to ±3.0 m, inclusions of silt till to 4 cm 2.9 to 3.1 m, rusty coloured lamina of fine sand (0.5 cm thick) at 5.4 m, occasional indistinct laminations below 5.5 m, increasing silt, sand and pebble content below ±7.0 m, gradational lower contact, hard to very stiff (Halton Till)			2	SS	33	19		
				3	SS	18	20		
				4	SS	16	12		
8.3				5	SS	15	11		
	SILT TILL: brown silt till, variable with sandy and clayey zones, occasional silty fine sand lamina and inclusions to 0.5 cm, 9.7 to 10.1 m silty sandy fine gravel, saturated, very dense (Lower Till)			6	SS	57	9		
11.0				7	SS	NA	NA	No recovery	
	CLAYEY SILT TO CLAYEY SILT TILL: brown clayey silt to clayey silt till, interbedded and gradational, occasional pebble, silty sandy medium gravel 15.0 to 15.1 m, hard (Lower Till)			8	SS	140	21		
				9	SS	124	12		
15.1				10	SS	100	8		
	SILTSTONE TO SHALE: reddish brown siltstone to shale, calcareous, with harder zones, occasional grey-green zones, weathered (Queenston Formation)								
18.3									
	Borehole terminated at 18.3 m in shale								
25									

Gartner Lee Associates Limited

BOREHOLE NO GL 84-4 (4N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE November 15/84

BOREHOLE TYPE 108 mm I.D.Hollow Stem Augers,Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 184 m (approximately) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: very dark greyish brown clayey silt topsoil, occasional root								
0.9	CLAYEY SILT TO SILTY CLAY: brown, mottled, heavily weathered, carbonate concretions			1	SS	39	14		
	CLAYEY SILT TO SILT TILL: brown clayey silt to silt till, fractures common to ±3.9m, indistinct banding 6.6 to 6.8 m, indistinct banding to laminations 11.3 to 13.4 m, silty sandy fine gravel 11.8 to 12.0 m indistict banding below ±17.0 m, decreasing pebble content and increasing clay below 18.7 m, laminated silt 19.3 to 19.4 m, hard to stiff (Halton Till)			2	SS	44	11		
				3	SS	23	13		
				4	SS	26	14		
				5	SS	22	10		
				6	SS	27	11		
				7	SS	25	11		
				8	SS	20	12		
				9	SS	25	13		
				10	SS	10	15		
				11	SS	12	12		
19.4				12	SS	15	15		
	COARSE SAND TO FINE GRAVEL: coarse sand to fine gravel, saturated, compact			13	SS	16	15		
20.9								No sample	
	SILT TILL: reddish brown silt till, variable, silty zone 23.4 to 23.6 m, numerous shale fragments, saturated, very dense (Lower Till)			14	SS	*	8	• 65/0.1 m →	
23.7									
	CLAYEY SILT: dark greyish brown clayey silt, laminated, reddish brown colour banding (continued)			15	SS	*	8	• 72/0.2 m →	

BOREHOLE NO GL 84-4 (4N) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE November 18/84

BOREHOLE TYPE 108 mm I.D.Hollow Stem Augers, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 184 m (approximately) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) Wp Wl COMMENTS
	CLAYEY SILT: (continued), occasional small (<1 cm) pebble, three stony bands 2 to 3 cm thick between 29.3 and 29.5 m, hard			16	SS	*	15	* 130/0.2 m	
				17	SS	*	17	* 135/0.2 m	
29.5				18	SS	*	17	* 117/0.2 m	
	SANDY SILT TILL: reddish brown sandy silt till, bouldery, possible gravel inclusions, very dense (Lower Till)			19	N/A	N/A	N/A		
	NOTE: poor sample recovery 28.5 to 40.0m								
35.0				20	SS	89	6		
	GRAVELLY MEDIUM TO COARSE SAND: reddish brown medium to coarse sand, very dense, saturated			21	SS	*	10	* 60/0.1 m	
37.1				22	SS	*	NA	* 70/0.1 m	
	CLAYEY SILT TILL: reddish brown clayey silt till, hard (Lower Till)			23	SS	*	NA	* 90/0.15 m	
40.0									
	SHALE TO SILTSTONE: reddish brown shale to siltstone, siltstone occurs as zones in shale ±1/3 volume, occasional grey-green coloured zones in rock, weathered and fractured (Queenston Formation)								
42.4									
	Borehole terminated at 42.4 m in shale								

BOREHOLE NO. GL 84-5 (4N)

PROJECT NAME Phase 4 A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE November 13/84

BOREHOLE TYPE 108 mm I.D.Hollow Stem Augers,Continuous Sampling GEOLOGIST EJK/AC

GROUND ELEVATION 179 m (approximately) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (Wp 10 20 30 Wl) COMMENTS
0.2	TOPSOIL: very dark greyish brown clayey silt to silty clay topsoil, occasional roots								
	SILT TO CLAYEY SILT TILL: dark greyish brown silt to clayey silt till, variable, massive to laminated, heavily weathered to ±1 m, discoloured fractures common to ±2.7 m, occasional fracture to ±4.0 m, increasing clay content below ±4.0 m, becoming laminated below 4.6 m, grading to laminated silt to fine sand with till-like bands (3 to 5 cm thick) from 5.4 to 6.6 m, sandy zone in till 7.7 to 7.8 m, grading to laminated silt 10.2 to 10.6 m, hard (Halton Till)			1	SS	34	13		
				2	SS	73	10		
				3	SS	26	13		
				4	SS	58	13		
				5	SS	38	11		
				6	SS	50	NA		
10.6				7	SS	50	15		
	SILT TO SANDY SILT TILL: brown to reddish brown silt to sandy silt till, variable, sandy zones, medium sand to fine gravel 11.6 to 12.0 m, increasing shale content below ±17 m (to 30 to 40%) saturated, dense to very dense (Lower Till)			8	SS	46	NA		
				9	SS	107	8		
				10	SS	*	9	* 50/0.06 m	
				11	SS	*	9	* 57/0.01 m	
18.8									
	SILTSTONE: reddish brown siltstone, minor shale, occasional grey-green zones, calcareous (Queenston Formation)								
21.4									
	Borehole terminated at 21.4 m in siltstone								

Gartner Lee Associates Limited

SITE PI-1N

BOREHOLE NO. GL 84-1(1N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** November 7, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger,Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 181 m (approximately) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
0-3	TOPSOIL: very dark greyish brown clayey silt topsoil, occasional root								
	SILT TO CLAYEY SILT TILL: brown to dark greyish brown silt to clayey silt till, heavily weathered to 1.4 m, discoloured fractures common to 4.2 m, numerous shale pebbles, colour change brown to grey at ±4.1 m, hard to very stiff (Halton Till)			1	SS	45	10		
				2	SS	32	12		
				3	SS	16	14		
5.7	SANDY SILT TILL: brown sandy silt till, occasional silt lamina to 2 cm in upper 0.5 m, numerous shale pebbles, decreasing pebble and sand content in lower 0.5 m, saturated, compact (Lower Till)			4	SS	12	10		
				5	SS	21	11		
8.7	SILT: grey silt to clayey silt, massive to laminated, very stiff			6	SS	24	16		
9.4	SAND: grey silty fine to coarse sand, laminated with occasional silt or clay lamina to 1 cm, saturated			7	SS	50	9		
10.7	SILT TO CLAYEY SILT TILL: brown to reddish brown silt to clayey silt till, massive, numerous shale fragments, increasing pebble content with depth, hard (Lower Till)			8	SS	*	11	*75/0.15m →	
				9	SS	*	9	*82/0.15m →	
15.2	SILTY FINE TO COARSE SAND: brown to reddish grey silt, fine to coarse sand, laminated, with occasional clayey silt interbed to 10 cm in upper 1 m, very loose to very dense, saturated			10	SS	54	23		
17.0				11	SS	0	16	spoon sank	
	SILT TILL: grey to reddish grey clayey silt to sandy silt till, variable, increasing sand and pebble content with depth, two silt interbeds, to 0.4m between 18.2 and 18.8 m, saturated, very dense (Lower Till)			12	SS	111	11	→	
				13	SS	118	14	→	
21.7				14	SS	60	12		
	SILTSTONE TO SHALE: reddish brown to light grey-green calcareous siltstone with shale interbeds, approximately 2/3 siltstone, 1/3 shale interbeds (Queenston Formation)			15	SS	N/A	N/A	no sample	
25.7				16	SS	*	8	*80/0.15m →	

Borehole terminated at 25.6 m in shale

Gartner Lee Associates Limited

BOREHOLE NO. GL 84-2 (1N)

PROJECT NAME Phase 4A Drilling & Sampling

CLIENT Ontario Waste Management Corporation **DATE** November 17, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 180 m. (approximately) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — WL)
0.2	FILL: dark brown sand and gravel								
0.4	TOPSOIL: very dark greyish brown clayey silt topsoil			1	SS	23	17		
	SILT TO CLAYEY SILT TILL: brown silty to clayey silt till, heavily weathered to ±1.5 m, numerous fractures to ±3.0 m, occasional discoloured fracture to ±3.8 m, increasing sand content in till below 5.6 m, sand laminae to 2 cm at 6.6 and 7.2 m, very stiff to hard (Halton Till)			2	SS	45	12		
				3	SS	42	11		
				4	SS	43	9		
8.5				5	SS	47	10		
	SANDY TO CLAYEY SILT TILL: brown sandy to clayey silt till, variable, with silt, sand and gravel zones and beds, silty sandy fine gravel bed 9.7 to 9.8 m, massive to indistinctly laminated, saturated, very dense (Lower Till)			6	SS	95	10		
				7	SS	86	7		
				8	SS	53	9		
				9	SS	53	20		
	- gravelly coarse to medium sand bed (14.9 to 15.1 m)			10	SS	114	8		
17.6				11	SS	103	8		
18.7	INTERBEDDED SILT AND TILL: brown interbedded laminated clayey silt and clayey silt till hard (Lower Till)			12	SS	80	21		
20.9	SILTY FINE SAND TO SILTY SANDY GRAVEL: reddish brown silty fine sand to silty sandy gravel (to 6 cm), laminated, saturated, very dense			13	SS	*	N/A	*50/0.01m no sample	
	SILT TILL: reddish brown silt to sandy silt till, variable, with inclusions of laminated clayey silt in upper 1 m, gravelly zones, numerous shale fragments, saturated, very dense (Lower Till)			14	SS	*	17	*49/0.07m	
				15	SS	*	N/A	*75/0.02m no sample	
23.8	SHALE AND SILTSTONE reddish brown shale with calcareous siltstone zones, weathered zones, shale is fine bedded, occasional grey-green zone (Queenston Formation)								

Gartner Lee Associates Limited

BOREHOLE NO. GL 84-2(1N) (Continued)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE November 17, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Augers, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 180 m (approximately) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
27.5	SHALE AND SILTSTONE: (continued)								
	Borehole terminated at 27.5 m in shale								

BOREHOLE NO. GL 84-5 (1N)

PROJECT NAME Phase 4a Drilling and Sampling

CLIENT Ontario Waste Management Corporation — DATE November 6, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Augers, Continuous Sampling — GEOLOGIST AB/AC

GROUND ELEVATION 186 m (approximately) — PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: brown clayey silt topsoil, numerous roots and organic matter								
0.9	CLAYEY SILT: brown clayey silt, occasional pebble, heavily weathered, numerous stained fractures			1	SS	30	14		
				2	SS	42	14		
				3	SS	17	13		
	SILT TO CLAYEY SILT TILL: dark greyish brown to reddish brown silt to clayey silt till, numerous shale fragments, numerous fractures to 4.0 m, occasional clay, silt or fine sand laminae to 5 cm thick below 8.5 m, becoming variable below ±9.0 m, becoming laminated below 10.5 m, very stiff to hard (Halton Till)			4	SS	N/A	9	no "N" value	
				5	SS	48	9		
				6	SS	67	16		
				7	SS	101	7	→	
11.6	SANDY SILT TO SILTY SAND TILL: brown sandy silt to silty sand till, variable, with silt and sand laminae zones and interbeds to (0.7 m thick) till dominant overall but sand dominant over smaller intervals, saturated, very dense (Lower Till)			8	SS	*	9	*78/0.15m →	
				9	SS	*	15	*75/0.08m →	
14.7	FINE TO COARSE SAND: very fine to coarse sand, laminated, occasional silty zone or clayey silt lamina, includes till interbeds to 0.6 m thick gradational to units above and below, very dense, saturated			10	SS	*	17	*64/0.15m →	
				11	SS	*	37	*69/0.15m →	
				12	SS	*	14	*105/0.15m →	
				13	SS	*	16	*75/0.08m →	
20.9	SANDY SILT TO SILTY SAND TILL: dark grey to reddish brown silty sand till, occasional silt to fine sand lamina interbeds (to 30 cm thick) and zones, increasing sand and gravel content with depth, abundant reddish brown shale, gradational contact with bedrock, saturated, very dense (Lower Till)			14	SS	*	13	*100/0.15m →	
				15	SS	*	7	*75/0.05m →	
				16	SS	*	7	*80/0.05m →	

BOREHOLE NO. GL 84-5 (1N) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE November 6, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Augers, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 186 m (approximately) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
	SILTY SAND TILL (continued) (Lower Till)			17	SS	*	8	*80/0.05m →	•
26.4									
	SILTSTONE AND SHALE: reddish brown calcareous siltstone and interbedded shale, occasional grey-green zones, fractured. (Queenston Formation)								
27.7	Borehole termianted at 27.7 m in shale								

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8.3.2 GARTNER LEE ASSOCIATES LIMITED, BOREHOLE AND TEST PIT LOGS, 1976-1979.

Site LF-4n and Vicinity from Gartner Lee Associates Limited, 1980.

Borehole locations within the LF-4N study area are shown in Figure 4 (in map pocket).

Boreholes were advanced using a hollow stem auger and standard split spoon samples were taken at intervals through the auger for stratigraphic control.

Additional boreholes were drilled at most locations to install ground water monitors.

The 1976 borehole elevations (in feet above sea level) were provided by M.M. Dillon Limited.

The 1979 borehole elevations (in feet above arbitrary datum) were provided by Gartner Lee Associates Limited.

All borehole elevations in Figure 4 are above sea level and are shown to the nearest metre.

Only boreholes within the study area are included.

GLAL BOREHOLE LOGS, 1976-1979

BOREHOLE NO. GL-1

PROJECT NAME Proposed Halton Landfill Site "F" **PROJECT NO.** 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited **DATE** 5/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers **GEOLOGIST** EGA/RL

ELEVATION 618.59 **TECHNOLOGIST**

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till:						
		Grey Brown clayey silt till, Queenston shale fragments	1	SS	39			
			2	SS	32			
			3	SS	55/6		▲ ▲	Installed April 1977 see borehole GL-1A
27.5		Sandy Silt Till:						
		Brown, sandy silt till, occasional sand lenses, cobbles locally, saturated, very dense, seepage seams	4	SS	50/2		●	
			5	SS	50/7			
46.0'		Shale Till Complex:						
		Red shaley silt till. Many weathered angular shale fragments very dense.	6	SS	50/2			
			7	SS	50/2			
58.0'		Red Queenston Shale:					●	
61.5'		Hole terminated at 61.5' in Queenston Shale.						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-1A

PROJECT NAME Halton Site 'F' — PROJECT NO. 76-71
CLIENT Regional Municipality of Halton — DATE April 25, 1977
BOREHOLE TYPE CME-45, Solid Stem Auger — GEOLOGIST D.K.
ELEVATION _____ — TECHNOLOGIST _____

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0		Clayey Silt Till: Mottled grey and brown fractured till-oxidized to brown around fractures. Low pebble content.	1	SS	18	18		
			2	SS	25	14		
			3	SS	36	11		
9		Clayey Silt Till: Reddish-brown massive till with low pebble content, changing to reddish-grey from 14' to 15'. Very compact.	4	SS	46	10		
			5	SS	44	11		grout seal
			6	SS	58	10	▽	sand pack
20.7		Borehole terminated in clayey silt till.	7	SS	>100	9		

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. GL-2

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 6/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 618.11 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till:						
		Grey brown clayey silt till, Queenston shale fragments	1	SS	34			
			2	SS	48		▲	▲ ← installed April 1977
			3	SS	50/5			
26.0'		Sandy Silt Till						
		Brown sandy silt till, very dense, saturated. seepage seams	4	SS	50/4			
			5	SS	50/4			
46.0'		Shale Till Complex:	6	SS	50/1		●	
49.0'		Red Shaley Silt till Red Queenston Shale	7	SS	50/3			
51.0'		Hole terminated at 51.0' in Queenston shale						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-3

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 7/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 612.05 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till: Grey brown clayey silt till, shale fragments, hard DTPL	1	SS	40			
			2	SS	27		▲ ▲	installed April 1977
		Becomes grey silty clay till after 20', WTPL	3	SS	9		●	
			3A	SS	5			
28.0'		Sandy Silt Till: Brown sandy silt till, sand lenses, saturated, very dense, seepage seams	4	SS	50/5			
			5	SS	50/4			
			6	SS	50/2			
			7	SS	50/3			
57.0'		Shale Till Complex: Red Shaley Silt till	8	SS	50/2		●	
69.1		Hole terminated at 69.1 on Queenston Shale						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-4

PROJECT NAME Proposed Halton Landfill Site "F" **PROJECT NO.** 76-71
CLIENT Region of Halton c/o M.M. Dillon Limited **DATE** 12/10/76
BOREHOLE TYPE 3¼" Hollow Stem Flight Augers **GEOLOGIST** EGA/RL
ELEVATION 601.93 **TECHNOLOGIST**

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till Grey brown clayey silt till, Queenston shale fragments	1	SS	24			
			2	SS	24			
			3	SS	18		▲	▲ installed April 1977
			4	SS	15		▲	
			5	SS	18		●	
			6	SS	14			
			7	SS	14			
			8	SS	50/2			
			9	SS	50/3			
84.0'		Sandy Silt Till: Brown sandy silt till,						
90.0'								

● Piezometer ▲ Standpipe

Gartner Lee Associates Limit

BOREHOLE NO. GL-4 (cont'd)

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71
CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 12/10/76
BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL
ELEVATION — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
90.0'		Clayey Silt: Well-sorted grey lacustrine clayey silt.	10	SS	81		●	
		Sand and Gravel: Brown sand and gravel, saturated.	11	SS	130/6			
			12	AS				
		Hole terminated at 120.0' in sand and gravel						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-5

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 22/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 603.03 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till Grey brown clayey silt till, becomes silty clay till locally	1	SS	52			
			2	SS	67			
		becomes grey after 20' ±	3	SS	9		▲	
			4	SS	48			
			5	SS	64			
			6	SS	50/3			
			7	SS	50/3			
68.0'		Sandy Silt Till: Brown sandy silt till, sand layers, seepage seams					●	
80'0"		Hole terminated at 80.0'.						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-6

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71
CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 12/10/76
BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL
ELEVATION 609.75 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till:						
		Grey brown clayey silt till, shale fragments	1	SS	60			
			2	SS	50		▲	
			3	SS	26			
			4	SS	70		●	
36.0		Sandy Silt Till:						
		Brown sandy silt till, sand seepage seams, saturated.	5	SS	50/2			
			6	SS	50/1.5			
			7	SS	50/2			
			8	SS	50/2			
			9	SS	50/2			
88.0		Shale tillcomplex	10	SS	50/2		●	

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-7

PROJECT NAME Proposed Halton Landfill Site "F" PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited DATE 13/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers GEOLOGIST EGA/RL

ELEVATION 613.65 TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till						
		Grey brown clayey silt till, shale fragments	1	SS	47			
			2	SS	52			
			3	SS	43		▲	
24.0		Sandy Silt Till: Brown sandy silt till, saturated, very dense, sand seepage seams	4	SS	50/5			
			5	SS	50/2		●	
			6	SS	50/2			
			7	SS	50/2			
			8	SS	50/2			
			9	SS	50/2			
79.0		Shale Till Complex:	10	SS	50/2		●	
83.0		Hole terminated at 83.0 on shale						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-8

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 19/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RI

ELEVATION 623.59 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till:						
		Brown clayey silt till, shale fragments	1	SS	67			
			2	SS	50/4			
18.0'		Sandy Silt Till: Brown sandy silt till, sand seams, saturated.	3	SS	56/6		▲	
26.0'		Shale Till Complex: Red shaley silt till, many angular Queenston shale fragments.	4	SS	50/6		●	
38.0'		Borehole terminated at 38.0' on Queenston Shale						

● Piezometer ▲ Standpipe

BOREHOLE NO. GL-9

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 14/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 634.41 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till:						
		Brown clayey silt till DTPL	1	SS	51			
12.0'			2	SS	30/3		▲	
		Shale Till Complex	3	SS	30/1		●	
16.5'		Hole terminated at 16.5' on Queenston Shale						

● Piezometer ▲ Standpipe

BOREHOLE NO GL-10

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 14/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 642.71 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till: Brown clayey silt till, DTPL	1	SS	92			
			2	SS	50/2			
16.0'		Shale Till Complex: Red shaley silt till, many angular shale fragments	3	SS	50/1		▲	
			4	SS	50/5			
21.0'		Queenston Shale: Red thinly layered shale.					●	
39.0'		Hole terminated at 39.0'						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-11

PROJECT NAME Proposed Halton Landfill Site "F" **PROJECT NO.** 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited **DATE** 7/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers **GEOLOGIST** EGA/RL

ELEVATION 621.84 **TECHNOLOGIST**

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till: Brown to grey brown clayey silt till, DTPL	1	SS	48			
			2	SS	50/5			
17.0'		Shale Till Complex:					▲	
		Borehole terminated at 20.1' on Queenston Shale.	3	SS	50/5			

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-12

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 8/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 616.75 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till Brown clayey silt till	1	SS	53		▲	
			2	SS	50/4			
14.0'		Sandy Silt Till: Brown sandy silt till, saturated, sand seams	3	SS	50/2			
			4	SS	50/3			
32.0'		Shale Till Complex: Red shaley silt till	5	SS	50/2		●	
43.0'		Hole terminated at 43.0' in shale till complex						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. ~~GL-~~13

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 8/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 642.77 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till:						
			1	SS	74			
12.0			2	SS	50/3		▲	
		Queenston Shale:						
14.5			3	SS	50/2			
		Hole terminated at 14.5' in red Queenston shale.						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-14

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 26/10/76

BOREHOLE TYPE 601.32 — GEOLOGIST EGA/RL

ELEVATION — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till						
		Grey brown clayey silt till, shale gragments	1	SS	57			
			2	SS	82			
			3	SS	18			installed April 1977.
			4	SS	53			
			5	SS	60			
			6	SS	62			
			7	SS	50/6			
68.0'		Sandy Silt Till: Brown sandy silt till, sand seams, saturated	8	SS	50/5			
90.0'		Hole terminated at 90.5'.	9	SS	50/5			

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-15

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 27/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 601.79 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till Grey brown clayey silt till, shale fragments locally more clayey. Silty sand till lens at 20'± (seepage zone)	1	SS	63			
			2	SS	93		▲	installed April 1977 see borehole GL-15A
			3	SS	50		▲	installed April 1977
			4	SS	19		▲	
			5	SS	32		●	
58.0'		Sandy Silt Till: Probably transitional into underlying sand.	6	SS	24			
		Sand Grey coarse sand, some gravel layers, saturated	7	SS				
			8	SS				
78.0'		Shale Till complex:	9	SS	50/6		●	
80.5'		Hole terminated at 80.5' in shale till complex						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-15A

PROJECT NAME Halton Site 'F' — PROJECT NO. 76-71
CLIENT Regional Municipality of Halton — DATE April 26, 1977
BOREHOLE TYPE CME-55, Solid Stem Auger — GEOLOGIST D.K.
ELEVATION — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
0		Clayey Silt Till Mottled grey and brown, fractured with oxidation haloes around fractures. Fracture frequency decreases with depth	1	SS	14	15		Grout seal
								Sand pack
7'			2	SS	24	15		
		Clayey Silt Till Increasing pebble content with depth. No visible fractures below 11'. Colour changes from brown to greyish purple-brown from 12' to 15'.	3	SS	28	13	▲	
			4	SS	33	12		
			5	SS	16	12		Grout seal
			6	SS	13	13		Sand pack
20'		Seam of medium-coarse grey sand or sand till from 20' to 21'.	7	SS	17	9	▲	
21.5		Hole terminated in clayey silt till.						

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. GL-16

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 28/10/76 - 1/11/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 603.36 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till: Brown clayey silt till, shale fragments	1	SS	37			
			2	SS	50/6			
			3	SS	21		▲	
		becomes grey after 35'	4	SS	25			
			5	SS	51			
			6	SS	50/6		●	
60.0'		Hole terminated at 60.0' in till.						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-17

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 1/11/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 604.70 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till: Brown clayey silt till, shale fragments	1	SS	55			
			2	SS	41			
			3	SS	48			
			4	SS	50/4		▲	
34.0'		Sandy Silt Till: Grey brown sandy silt till, seepage seams saturated	5	SS	50/2			
44.0'		Shale Till Complex Red shaley silt till	6	SS	50/2		●	
53.0'		Hole terminated at 53.0' in shale till complex.						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-18

PROJECT NAME Proposed Halton Landfill Site "F" **PROJECT NO.** 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited **DATE** 2/11/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers **GEOLOGIST** EGA/RL

ELEVATION 600.27 **TECHNOLOGIST**

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till: Brown clayey silt till, many shale fragments	1	SS	44			
			2	SS	56			
							▲	installed April 1977
			3	SS	17		▲	
			4	SS	33			
			5	SS	42		●	
			6	SS	29			
		Brown silty fine sand seam, saturated	7	SS	50/6			
			8	SS	67			
75.0		Sandy Silt Till: Brown sandy silt till, very dense, saturated.	9	SS	50/2			
		Hole terminated at 91.5' in sand till	10	SS	65		●	

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-19

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 3/11/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 600.05 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till; Grey brown clayey silt till, shale fragments	1	SS	50			
			2	SS	19			
							▲	installed April 1977.
			3	SS	16		▲	
			4	SS	54			
			5	SS	30/3			
45.0		Sandy Silt Till: Brown stony sandy silt till, very dense, saturated	6	SS	30/3			
			7	SS	30/2		●	
65.2		Hole terminated at 65.2' in silty sand till.	8	SS				

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. 1-1

PROJECT NAME HALTON SITE 'F' CONTINUED — PROJECT NO. 79-112
CLIENT M. M. DILLON LIMITED — DATE SEPT. 26, 1979
BOREHOLE TYPE 3¼" I.D. Hollow Stem Augers — GEOLOGIST E.G.A.
ELEVATION 100.6 — TECHNOLOGIST L.L.

DEPTH ELEV. Ft.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
0'6"		TOPSOIL						
		GLACIAL TILL brown clayey silt till with minor shale fragments - dense to compact, wet.	1	SS	28	15		
			2	SS	41	11		
			3	SS	44	13		
			4	SS	48	11		saturated
			5	SS	27	12		
			6	SS	17	12	▲	
			7	SS	11	14		
			8	SS	5	18		
			9	SS	12	19		
24'0"								
25'6"		FINE SAND dark grey silty fine sand, saturated	10	SS	56	8	●	
			11	SS	66	3		
		GLACIAL TILL grey brown clayey silt till with very minor fine sand lenses from 27'6"± to 30'0"± very dense - saturated	12	SS	61	5		
			13	SS	52	10		
			14	SS	57	10		
			15	SS	41	13		
			16	SS	32	11	●	
41'6"		Borehole terminated at 41'6" in clayey silt till						

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 12

PROJECT NAME HALTON SITE 'F' CONTINUED — PROJECT NO. 79-112
CLIENT M. M. DILLON LIMITED — DATE Sept. 27, 1979
BOREHOLE TYPE 3¼" I.D. Hollow Stem Augers — GEOLOGIST E.G.A.
ELEVATION 93.7 — TECHNOLOGIST L.L.

DEPTH ELEV. Ft.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
0'6"		TOPSOIL						
		GLACIAL TILL medium brown clayey silt till with mixed shale fragments compact to dense - wet	1	SS	19	13		
			2	SS	30	13		saturated
			3	SS	33	12		
			4	SS	31	12		
			5	SS	26	13		
			6	SS	7	14		
		change to grey	7	SS	11	12	▲	
			8	SS	19	10		
			9	SS	21	10		
			10	SS	26	10		
			11	SS	27	9		
			12	SS	31	11		
			13	SS	30	11		
			14	SS	19	11		
			15	SS	23	11		
			16	SS	24	12	●	
41'6"		Borehole terminated at 41'6" in clayey silt till						

● Piezometer Tip ▲ Standpipe Tip

BOREHOLE NO. L-3

PROJECT NAME HALTON SITE 'F' CONTINUED — PROJECT NO. 79-112
CLIENT M. M. DILLON LIMITED — DATE Sept. 27, 1979
BOREHOLE TYPE 3¼" I.D. Hollow Stem Augers — GEOLOGIST E.G.A.
ELEVATION 99.5 — TECHNOLOGIST L.L.

DEPTH ELEV. Ft.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
0'7"		TOPSOIL						
		GLACIAL TILL medium brown clayey silt till with minor fractures, and with mixed shale fragments - compact - wet	1	SS	39	10		
			2	SS	35	11		saturated
			3	SS	40	11		
			4	SS	42	13		
			5	SS	24	11		
		change to grey	6	SS	13	13		
			7	SS	20	10	▲	
			8	SS	15	12		
			9	SS	14	14		
			10	SS	13	19		
			11	SS	26	10		
			12	SS	35	10		
			13	SS	42	10		
			14	SS	35	12		
			15	SS	26	10		
			16	SS	24	17	●	
41'6"		Borehole terminated at 41'6" in clayey silt till						

● Piezometer Tip ▲ Standpipe Tip

GLAL TEST PIT LOGS, 1976-1979

April 19, 1977

TEST PIT LOGS
HALTON SITE 'F'

Test Pit # 1

Pit was excavated to expose the standpipes GL-14-11, with one wall of the pit intersecting the borehole.

0 - 1' Black loamy topsoil.

1 - 4.5' Very fractured mottled gray and brown till. Fractures oxidized, irregular, with poorly defined horizontal habit. Fracture seepage from 3 to 4.5'; blocks appear to be under saturation. Friable texture.

4.5 - 10' Massive brown-gray clayey silt till with minor fracturing decreasing with depth. Pebble content increases with depth with some boulders > 1' below 9'. No seepage. Friable, increasingly blocky with depth.

Hole terminated at 10'.

NOTES: The standpipe borehole was full of water over the entire exposed length, indicating that fracture flow in the upper 4.5' of the till is entering the borehole below the upper bentonite seal. This may give rise to erroneous water table readings in many of the standpipes. Water in the fractured till

represents recent spring infiltration. This water is transient and may perch above the true water table, dissipating through evapo-transpiration and interflow before equilibrating with the water table.

Test Pit # 2

Pit excavated 10' north of a stock pond located approximately 300' north of GL-14.

0 - 1.5'	Black to brown friable clay loam topsoil.
1.5 - 6'	Very fractured clayey silt till, mottled by oxidation haloes around fractures. Fractures irregular but preferentially near horizontal. Till is predominantly gray to 3', increasingly brown to 6'. Considerable fracture seepage over the entire unit was accomplanied by slumping of the pit walls.
6 - 10'	Very compact red-brown clayey silt till with low pebble content and occasional boulder. No significant fracturing visible. Till has blocky habit, breaking into platy fragments. No seepage even after one hour, and no slumping was observed.

Hole terminated at 10'.

Test Pit #3

Located at the intersection of the Kowal, Mogil and Freeman properties, on a height of land.

0 - 1.5'	Black to brown (with depth) friable clay loam topsoil.
1.5 - 3.5'	Mottled gray-brown fractured till, quite red below 3' due to high Queenston shale content. Fractures oxidized and irregular, with horizontal habit. No seepage.
3.5 - 6'	Transition zone from fractured to massive till. Increasing red shale content with depth. By 5' fractures are widely spaced, and till breaks into blocks several inches in dimension. Secondary gypsum was observed in several fractures from 4 to 6'. Its presence indicates discharge conditions and approximately defines the water table.
6 - 9'	Very compact red clayey silt till with many highly weathered Queenston shale fragments and blocks. No visible fracturing or seepage.

Hole terminated at 9'.

Test Pit # 4

Located by the south corner of the woodlot on the Delvigne property, in low, waste ground.

0 - 2'	Black to brown (with depth) clayey soils, very plastic.
2 - 6'	Very fractured mottled gray and brown clayey silt till. Increasing Queenston shale content with depth makes the till progressively redder. Considerable seepage from 2 to 6' accompanied by rapid slumping of the fractured till.
6 - 10'	Very compact red-brown clayey silt till with abundant weathered shale. Only minor fracturing, disappearing at 8'. No seepage. Blocky habit.
	Hole terminated at 10'.

8.3.3 MORRISON BEATTY LIMITED, BOREHOLE LOGS, 1984

- Covering letter
- Site LF-4N
- Site PI-1N

Borehole locations within the LF-4N study area are shown in Figure 4 (in map pocket).

Continuous samples were obtained by advancing a large split tube (8.9 cm x 152 cm) through the hollow stem augers.

Ground elevations at the boreholes are estimated from the contours on the 1:10 000 scale base maps and are rounded to the nearest metre in Figure 4.

Only boreholes within the study area are included.

morrison beatty limited
consulting engineers and hydrogeologists
4500 dixie road, unit 12a, mississauga, ontario L4W 1V7 (416-624-9308)

November 9, 1984

Mr. Ken Goff
Gartner Lee Associates Limited
Toronto-Buttonville Airport
Markham, Ontario
L3P 3J9

Dear Sir:

re: Hydrogeologic Studies
of the
Milton Sites for OWMC
Our File No. 413-841

This letter confirms our meeting today at 10:00 a.m. to discuss our work at OWMC Sites No. PI-1N and LF-4N.

We have enclosed preliminary copies of the borehole logs at the four locations we tested at each site. Maps showing the test locations and private well locations are also included.

The well logs are abbreviated, since detailed examination of the borehole samples has not been completed. They show the significant stratigraphic units only.

Yours very truly,
MORRISON BEATTY LIMITED

Brian W. Beatty, P.Eng.

NJR/dc

SITE LF-4N

morrison beatty limited
consulting engineers and hydrogeologists

4N-OW1

CLIENT _____ FILE NO 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site LF-4N)

GEOLOGIST / ENGINEER TH DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL	3	10	
	6	20	
	9	30	
	12	40	
	15	50	
STRATIFIED DRIFT	18	60	
TILL	21	70	
	24	80	
	27	90	
	30	100	
	33	110	
SHALE	36	120	
	39	130	
	40		

morrison beatty limited
consulting engineers and hydrogeologists

4N-OW2

CLIENT _____ FILE NO. 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site LF-4N)

GEOLOGIST / ENGINEER TH DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL: with some silt and clay layers	3	10	
	6	20	
	9	30	
SILT/SAND: with some till layers	12	40	
TILL: with some silt and clay layers	15	50	
	18	60	
STRATIFIED DRIFT	21	70	
TILL	24	80	
	27	90	
	30	100	
STRATIFIED DRIFT	33	110	
SHALE	36	120	
	39	130	
	40		

morrison beatty limited
consulting engineers and hydrogeologists

4N-OW3

CLIENT _____ FILE NO. 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site LF-4N)

GEOLOGIST / ENGINEER TH DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL: with some silt and clay layers	3	10	
	6	20	
	9	30	
	12	40	
STRATIFIED DRIFT	15	50	
	18	60	
TILL: with some silt and clay layers	21	70	
	24	80	
	27	90	
STRATIFIED DRIFT	30	100	
SHALE	33	110	
	36	120	
	39	130	
	40		

morrison beatty limited
consulting engineers and hydrogeologists

4N-OW4

CLIENT _____ FILE NO 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site LF-4N)

GEOLOGIST / ENGINEER TH DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL	3	10	
	6	20	
	9	30	
	12	40	
STRATIFIED DRIFT	15	50	
TILL	18	60	
STRATIFIED DRIFT	21	70	
TILL	24	80	
	27	90	
STRATIFIED DRIFT			
TILL	30	100	
STRATIFIED DRIFT	33	110	
	36	120	
	39	130	
	40		

SITE PI-1N

morrison beatty limited
consulting engineers and hydrogeologists

1N-OW2

CLIENT _____ FILE NO. 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site PI-1N)

GEOLOGIST / ENGINEER TH DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL: clayey silt	3	10	
	6	20	
TILL: silty sand	9	30	
	12	40	
SHALE	15	50	
	18	60	
	21	70	
	24	80	
	27	90	
	30	100	
	33	110	
	36	120	
	39	130	
	40		

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1N-OW4

CLIENT

FILE NO 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site PI-1N)

GEOLOGIST / ENGINEER TH DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL	3	10	
	6	20	
	9	30	
STRATIFIED DRIFT			
TILL	12	40	
	15	50	
STRATIFIED DRIFT	18	60	
SHALE	21	70	
	24	80	
	27	90	
	30	100	
	33	110	
	36	120	
	39	130	
	40		

8.3.4 HYDROLOGY CONSULTANTS, BOREHOLE LOGS, 1984

Borehole locations are indicated in Figure 4.

Elevations provided on the borehole logs are rounded to the nearest metre in Figure 4.

Only boreholes within the study are are included.

SITE LF-4N

Borehole Log

Trow Ltd

Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Field Vane Test
Lab Vane Test
Natural Moisture
Plastic and Liquid Limit
Undrained Triaxial at Overburden Pressure
% Strain at Failure
Penetrometer

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg. No. Page 1
Borehole No. E1
Project No. T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m
		Topsoil, organics	183	0
		SILTY CLAY TILL: Reddish brown, mottled, weathered, wet below 0.3 m, prominent vertical fracture at 3.8 m hard, shale fragments		1
				2
				3
		Change to greyish brown		4
				5
		Silty sand lense 100 mm thick		6
				7
		Boulders		8
				9
		Change to reddish brown		
		Lost core due to boulder in sampler		10

N Value (ASTM D1586-CSA A119.1)
20 40 60 80
Shear Strength MPa

Natural Moisture Content and Atterberg Limits % Dry Weight
10 20 30

Natural Unit Weight kN/m³

Borehole Log

Trow Ltd

Auger Sample ⊠ | SPT (N) Value ○ ○ ▨ | Dynamic Cone Test ——— | Shelby Tube ● ● ■ | Field Vane Test +s | Lab Vane Test t

Natural Moisture x | Plastic and Liquid Limit ⊢—o | Undrained Triaxial at Overburden Pressure 0 15 5 10 | % Strain at Failure | Penetrometer ▲

Project HALTON ENVIRONMENTAL ASSESSMENT

Hole location and datum see drawing No. 1

Dwg. No. Page 2

Borehole No. E1

Project No T 3780-HY

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m	N Value (ASTM) D1586-CSA A119.1) 20 40 60 80 Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN/m³
				10			
				11			
				12			
				13			
			168.9	14			
		CLAY (Till Like): Grey, hard, grades to bedded silty clay, may be partly reworked lacustrine material, saturated fine sand layer between 14.8 and 15.3 m.		15			
			167.7				
		OUTWASH/TILL COMPLEX: Interbedded, brown, saturated, loose; 76 mm gravelly till, 203 mm silty sand; 76 mm sand & gravel; 76 mm silty sand; 15 mm sand & gravel; 51 mm sandy silt, etc.		16			
			165.4	17			
		CLAYEY SILT TILL: Red-brown, mottled, hard, lost core due to stone in sampler.		18			
				19			
			163.7				
		SAND AND GRAVEL TILL WITH SOME BOULDERS: Brown, saturated, loose to compact, sand lense 20.3 m to 20.6 m					

Borehole Log

Trow Ltd

Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Field Vane Test
Lab Vane Test

Natural Moisture
Plastic and Liquid Limit
Undrained Triaxial at Overburden Pressure
% Strain at Failure
Penetrometer

Project HALTON ENVIRONMENTAL ASSESSMENT

Dwg. No. Page 3
Borehole No. E1
Project No. T 3780-HY

Hole location and datum see drawing No. 1

G W L	SYMBOL	Soil Description	ELEV. m	DEPTH m	N Value (ASTM) D1586-CSA A119.1) 20 40 60 80 Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN/m³
				40			
				41			
				42			
				43			
				44			
				45			
		CLAYEY SILT TILL: Reddish brown, mottled, wet, hard interbedded with distorted silt and clay lenses, low stone content, appears to be reworked lacustrine material, occasional gravelly till layer	157.8	46			
				47			
				48			
				49			
				50			

Borehole Log

Page 4

Auger Sample | Natural Moisture | Project HALTON ENVIRONMENTAL | Dwg. No.
SPT (N) Value | Plastic and Liquid Limit | ASSESSMENT | Borehole No. E1
Dynamic Cone Test | Undrained Triaxial at Overburden Pressure | | Project No T 3780-HY
Shelby Tube | % Strain at Failure
Field Vane Test | Penetrometer
Lab Vane Test

Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH m	N Value (ASTM D1586-CSA A119.1) 20 40 60 80 Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN/m³
				50			
		SILTY SAND TILL WITH SOME GRAVEL: Brown, loose to compact, saturated	152.1	51			
		SAND AND GRAVEL	151.4				
		SANDY SILT TILL WITH SOME GRAVEL SIZES: Brown, dense, saturated, occassional 50 mm medium to coarse sand layers, interbedded fine to medium sand and silt below 34.1 m (appears to be reworked lacustrine material)	151.2	52			
				53			
			148.4	54			
		Borehole terminated at 34.6 m					
				55			
				56			
				57			
				58			
				59			
				60			

Borehole Log

Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Field Vane Test
Lab Vane Test

Natural Moisture
Plastic and Liquid Limit
Undrained Triaxial at Overburden Pressure
% Strain at Failure
Penetrometer

Project HALTON ENVIRONMENTAL ASSESSMENT
Hole location and datum see drawing No. 1

Dwg. No. Page 1
Borehole No. E2
Project No T 3780-HY

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH m
		TOPSOIL: Brown	187	0
		SILTY CLAY TILL: Brown, mottled, weathered to 2.59 m, hard shale fragments, moist below 0.3 m, grey brown below 1.7 m, wet below 2.6 m		1 2 3 4 5 6 7 8
		CLAYEY SILT TILL: Brown, hard, saturated, shale fragments	178.7	9
		GRAVELLY SILT TILL: Loosely consolidated, may be a water laid till - no evidence of	177.7	10

N Value (ASTM D1586-CSA A119.1)
20 40 60 80
Shear Strength MPa

Natural Moisture Content and Atterberg Limits % Dry Weight
10 20 30

Natural Unit Weight kN/m³

Borehole Log

Auger Sample ⊠ | Natural Moisture ×
SPT (N) Value ○ ○ ▨ | Plastic and Liquid Limit ⊢—○
Dynamic Cone Test ——— | Undrained Triaxial at Overburden Pressure 0 / 15 ⊕ 5 / 10
Shelby Tube ● ● ■ | % Strain at Failure
Field Vane Test +s | Penetrometer ▲
Lab Vane Test ℄

Project HALTON ENVIRONMENTAL ASSESSMENT
Hole location and datum see drawing No. 1

Dwg. No Page 2
Borehole No. E2
Project No T 3780-HY

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH m	N Value (ASTM) D1586-CSA A119.1) 20 40 60 80 / Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN/m³
		bedding,occasional silt parting,coarse gravel is well rounded		10			
			176.4				
		SANDY SILT TILL: Red, brown, hard, moist, shale fragments, saturated, medium sand layer between 12.2 to 12.4 m, faint bedding, occasional small boulder sizes		11			
				12			
			170.8	13			
		SILTY SAND AND GRAVEL TILL: Brown, saturated, poorly sorted, compact, no bedding, pebbles break clean from sandy silt matrix		14			
			169.6				
		SILT TILL WITH SOME SAND: Brown, shale fragments, dense, fissile, saturated, becomes dry to moist at 15.4 m		15			
				16			
			167.0	17			
		SHALE/TILL COMPLEX: Zones of red shale and brown sandy silt till, dry		18			
			165.3				
		Hole terminated in red and green shale at 18.7 m		19			
				20			

Borehole Log

Trow Ltd

Auger Sample
SPT 'N' Value
Dynamic Cone Test
Shelby Tube
Field Vane Test +s
Lab Vane Test t

Natural Moisture w
Plastic and Liquid Limit
Undrained Triaxial at Overburden Pressure
% Strain at Failure
Penetrometer

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg. No. Page 1
Borehole No. E3
Project No. T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m
			184	0
		TOPSOIL: Greyish brown with organics	183.5	
		CLAYEY SILT TILL: Brown, weathered, iron stained fractures, mottled, dry, hard, shale fragments, thin sand lamination at 2.4 metres		1
				2
		Change to greyish brown, occasional silt layers, wet, hard		3
		SILTY SAND WITH SOME GRAVEL: Brown, gradations of fine- to coarse sand with some gravel and boulders, saturated	180.8	
		SANDY SILT TILL WITH SOME CLAY: Brown, weathered and mottled to 4.1 m, wet, hard	180.2	4
				5
				6
			177.9	
		SILTY SAND TILL: Brown, dense, dry, fewer gravel sizes than overlying till, occasional thin sand and silt, clayey, interbedded laminated silt layer between 13.2 and 13.6 m, interbedded red sand lenses (wet) between 13.6 and 14.0 m		7
				8
				9
				10

N Value (ASTM) D1586-CSA A119.1)
20 40 60 80
Shear Strength MPa

Natural Moisture Content and Atterberg Limits % Dry Weight
10 20 30

Natural Unit Weight kN/m³

Borehole Log

Trow Ltd

Auger Sample | SPT (N) Value | Dynamic Cone Test | Shelby Tube | Field Vane Test | Lab Vane Test

Natural Moisture | Plastic and Liquid Limit | Undrained Triaxial at Overburden Pressure, % Strain at Failure | Penetrometer

Project HALTON ENVIRONMENTAL ASSESSMENT

Dwg. No. Page 2

Borehole No. E3

Project No. T 3780-HY

Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH m
				10
				11
				12
				13
		SILT TILL: Grey brown, dense, saturated, shale fragments, occasional laminated silt zones	170	14
		SANDY GRAVEL TILL: Grey, brown, saturated, large stone fragments in fine sand matrix occacional zones of cross-bedded silt	169	15
		SHALE/TILL COMPLEX: Sand & greyish red shale	168.2	16
		Hole terminated at 16.6 m in red shale	167.4	17
				18
				19
				20

N Value (ASTM) D1586-CSA A119.1) 20 40 60 80 — Shear Strength MPa

Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30

Natural Unit Weight kN/m³

SITE PI-1N

Borehole Log

Natural Moisture
Plastic and Liquid Limit
Undrained Triaxial at Overburden Pressure
% Strain at Failure
Penetrometer
Cone Test

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg No Page 1
Borehole No D6
Project No T 3780-HY
Hole location and datum see drawing No 1

Soil Description	ELEV m	DEPTH m	N Value (ASTM) D1586-CSA A119.1) 20 40 60 80 Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN/m³
CLAYEY SILT TILL: Brownish grey, mottled, weathered, fragments of shale, moist, hard		0			
		1			
		2			
Changes to reddish brown, hard		3			
		4			
Moist to wet, very stiff		5			
SILTY CLAY TILL: Grey, fragments of shale, wet, very stiff		6			
		7			
SANDY SILT TILL: Brownish red, shale fragments, moist, hard		8			
		9			
SILTY CLAY TILL: Grey, wet, very stiff, rudimentary		10			

Borehole Log

Project HALTON ENVIRONMENTAL — Dwg No. Page 2

ASSESSMENT — Borehole No D6

Project No T 3780-HY

Hole location and datum see drawing No. 1

SYMBOL	Soil Description	ELEV m	DEPTH m
	bedding, may be reworked lacustrine material		0
	SANDY SILT TILL: Reddish brown, shale fragments, moist, hard		1
			2
			3
	SILT: Reddish brown, small quantities of sand and shale fragments, saturated, very stiff		4
			5
	END OF BOREHOLE		6
			7
			8
			9
			10

N Value (ASTM) D1586-CSA A119.1) — Shear Strength — MPa (20, 40, 60, 80)

Natural Moisture Content and Atterberg Limits % Dry Weight (10, 20, 30)

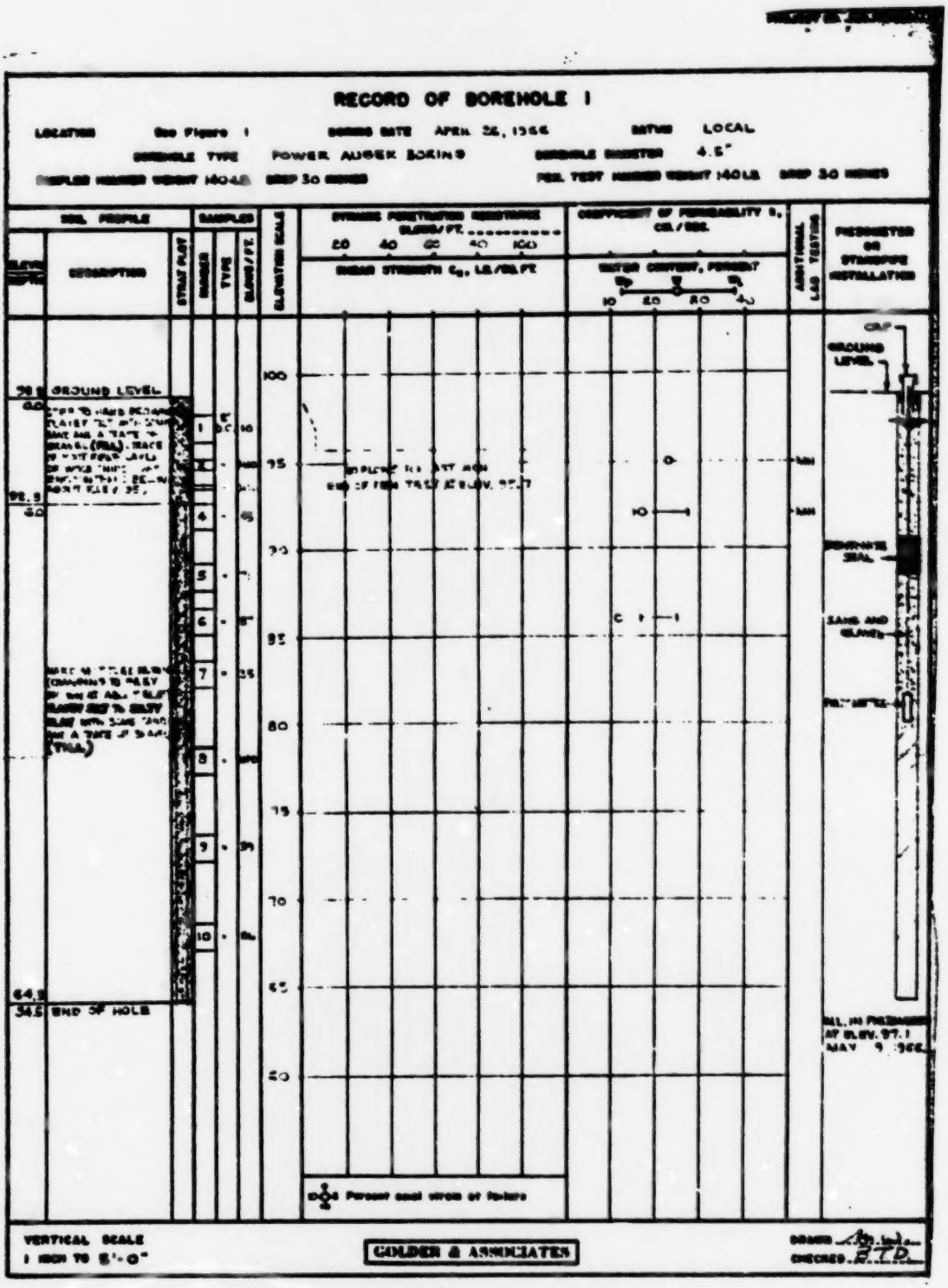
Natural Unit Weight kN/m3

Q 80/6"

Q 100/6"

8.3.5 MINISTRY OF TRANSPORTATION AND COMMUNICATIONS, BOREHOLE LOGS

Borehole elevations are provided to the nearest tenth of a foot from an arbitrary datum in the original data. Elevations have been rounded to the nearest metre in Figure 4.



RECORD OF BOREHOLE 1

LOCATION See Figure 1 BORING DATE APRIL 26, 1966 DATUM LOCAL

BOREHOLE TYPE POWER AUGER BORING BOREHOLE DIAMETER 4.5"

HAMMER WEIGHT 140 LB DROP 30 INCHES PEN. TEST HAMMER WEIGHT 140 LB DROP 30 INCHES

SOIL PROFILE | SAMPLES | DYNAMIC PENETRATION RESISTANCE, BLOWS/FT. (20 40 60 80 100) | SHEAR STRENGTH c_q, LB./SQ.FT. | COEFFICIENT OF PERMEABILITY k, CM./SEC. | WATER CONTENT, PERCENT (10 20 30 40) | ADDITIONAL LAB TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

ELEV.	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	BLOWS/FT.	ELEVATION SCALE
98.9	GROUND LEVEL					100
60	[illegible]		1	SC	10	
			2			95
98.9						
60			4			
			5			90
			6			85
			7		35	
						80
			8			
						75
			9		39	
						70
			10			
64.9						65
34.5	END OF HOLE					
						60

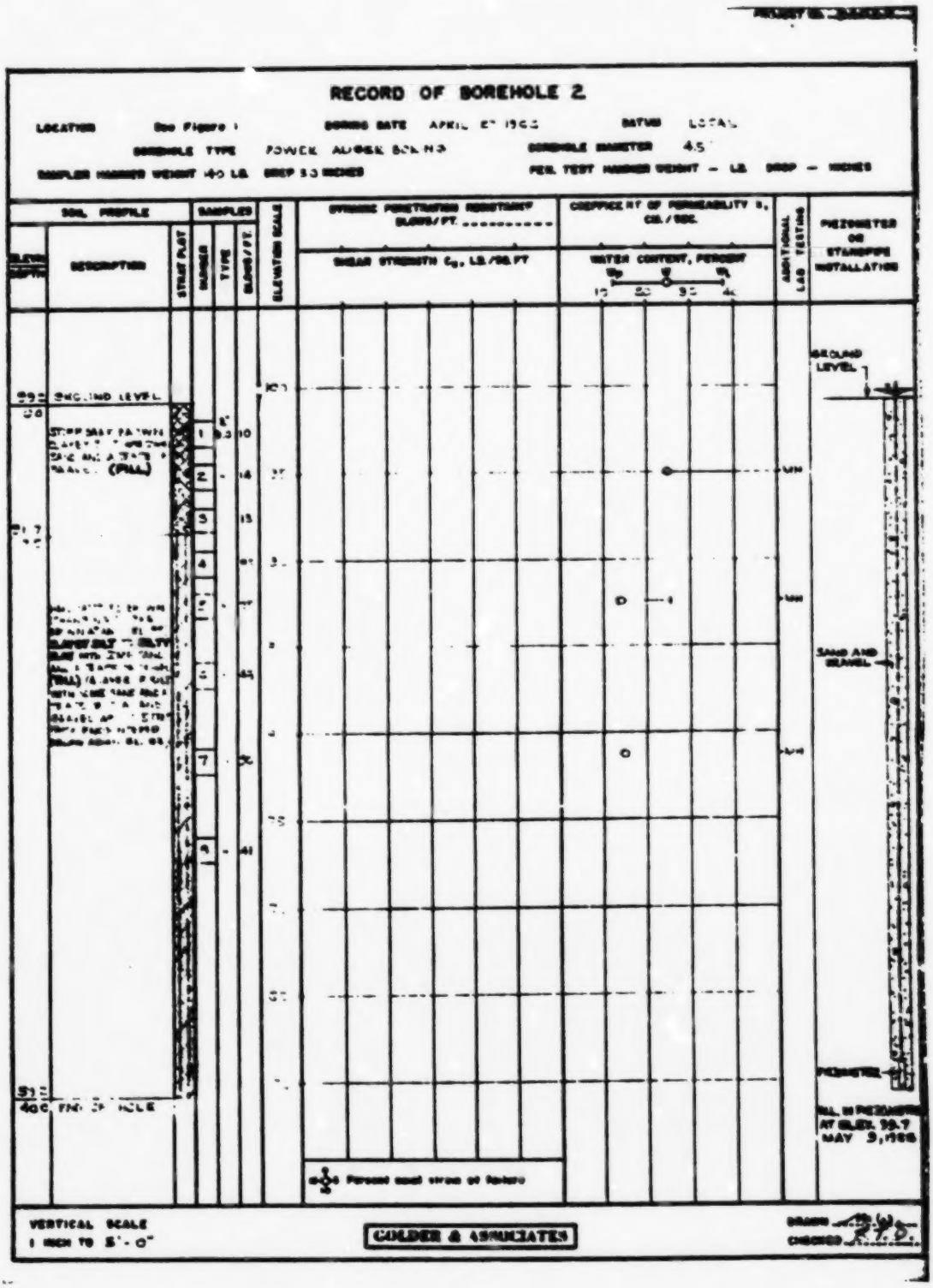
Percent axial strain at failure

Piezometer installed at Elev. 97.1 May 9, 1966

VERTICAL SCALE
1 INCH TO 5'-0"

GOLDER & ASSOCIATES

DRAWN [illegible] CHECKED R.T.D.



RECORD OF BOREHOLE 2

LOCATION See Figure 1 BORING DATE APRIL 27 1965 DATUM LOCAL

BOREHOLE TYPE POWER AUGER BORING BOREHOLE DIAMETER 4.5"

SAMPLER HAMMER WEIGHT 140 LB. DROP 30 INCHES PEN. TEST HAMMER WEIGHT — LB. DROP — INCHES

SOIL PROFILE | SAMPLES | DYNAMIC PENETRATION RESISTANCE BLOWS/FT. | COEFFICIENT OF PERMEABILITY k, CM./SEC. | ADDITIONAL LAB TESTING | PIEZOMETER OR STANDPIPE INSTALLATION

ELEVATION | DESCRIPTION | STRATA PLOT | NUMBER | TYPE | BLOWS/FT. | ELEVATION SCALE

SHEAR STRENGTH c_u, LB./SQ.FT. | WATER CONTENT, PERCENT

GROUND LEVEL

SAND AND GRAVEL

PIEZOMETER

FILL IN PIEZOMETER AT ELEV. 99.7 MAY 3, 1965

VERTICAL SCALE
1 INCH TO 5'-0"

COLDER & ASSOCIATES

DRAWN CHECKED

8.4 SUPPORTING CALCULATIONS AND METHODS

In 1856, the French hydraulics engineer Henry Darcy reported that flow through a porous medium is proportional to the head loss and inversely proportional to the distance travelled. The formulation of these relationships is called Darcy's Law and may be written as specific discharge (v) = hydraulic conductivity (K) x gradient (i). The specific discharge is the total discharge per unit area of the discharging porous medium and does not indicate the velocity of the water 'particles'. The velocity of the water (average linear velocity, $\bar{v}$) may be obtained by dividing the specific discharge (v) by the effective porosity (n) of the porous medium. Because effective porosity is always less than 1, the average linear velocity ($\bar{v}$) is always greater than the specific discharge (v).

$$\text{Average Linear Velocity } (\bar{v}) = \frac{\text{hydraulic conductivity (K) x gradient (i)}}{\text{effective porosity (n)}}$$

Once the above parameters are known for a porous medium, an average linear velocity may be calculated. The following example utilizes values typical of lateral flow in the fractured zone:

Lateral Ground Water Flow

- hydraulic conductivity (K) 1×10^{-7}
- lateral gradient (i) 0.004
- effective fracture porosity (n) 0.0001

$$\bar{v} = \frac{Ki}{n} = \frac{1 \times 10^{-7} \times 0.004}{0.0001} = 4.0 \times 10^{-6} \text{ m/s or } \sim 100 \text{ m/year.}$$

Vertical Ground Water Flow

The application of Darcy's Law to ground water flow through layered porous media when the layers have differing thicknesses and hydraulic properties is discussed in Freeze and Cherry (1979) and is summarized below with regard to the area under study. The layered porous media of interest here are the confining layer subunits which include the fractured and the unfractured zones of the Halton Till. Estimating the rates of ground water flow in each of these layers involves (1) the calculation of a single equivalent hydraulic conductivity for the two layers, (2) calculation of the specific discharge through the layers and (3) the calculation of average linear velocities in each of the layers.

The calculation of an equivalent hydraulic conductivity (Ke) for the three-layer situation is:

$$Ke = \frac{d(FCL + CL + LT)}{\frac{dFCL}{KFCL} + \frac{dCL}{KCL} + \frac{dLT}{KLT}}$$

where K and d are the hydraulic conductivity and thickness respectively and the subscripts are 'e' (equivalent), 'FCL' (fractured confining layer), 'CL' (confining layer), and 'LT' (lower till).

The calculation of specific discharge (v) uses the equivalent hydraulic conductivity (Ke) and the overall vertical gradient (i) across the layers in Darcy's Law:

$$v = Ki$$

And finally, the average linear ground water velocity ($\bar{v}$) in each layer is obtained by dividing the specific discharge (v) by the effective porosity (n) for each of the layers involved.

The following example uses numbers similar to those in the report (values relate to the layers identified above; thicknesses are in m and hydraulic conductivities are in m/s).

$$Ke = \frac{10.6}{\frac{5.0}{1\times10^{-7}} + \frac{5.6}{1\times10^{-9}}} = \frac{10.6}{5.7\times10^{-9}} = 1.9\times10^{-9} \text{ m/s}$$

where the vertical gradient (i) is 0.1

$$v = Kei = 1.9\times10^{-9}\times0.1 = 1.9\times10^{-10} \text{ m/s}$$

$$\text{or} \sim 5.9\times10^{-2} \text{ m/year.}$$

The average linear velocity ($\bar{v}$) = specific discharge ÷ porosity for each individual layer.

For the fractured confining layer, the effective porosity (n) = 0.0001 and the average vertical liner velocity ($\bar{v}$) =

$1.9 \times 10^{-10}/0.0001 = 1.9 \times 10^{-10}$ m/s or $\sim$ 60 m/year.

For the unfractured confining layer, no effective porosity value is available and consequently a total porosity of 0.3 is used to calculate an average linear velocity ($\bar{v}$) =

$$1.9 \times 10^{-10} / 0.3 = 6.0 \times 10^{-10} \text{ m/s}$$

$$\text{or} \sim 0.02 \text{ m/year.}$$

(These are approximate values and are usually rounded to one significant figure in the text).

The major assumptions for their calculations are:

(1) steady state flow
(2) flow in a direction perpendicular to the layering
(3) homogeneous and isotropic layers
(4) flow is governed by Darcy's Law. A more complete and theoretical discussion is given in Freeze and Cherry (1979).

For a more detailed discussion of ground water flow rates through the confining layer based on advection and diffusion calculations, the reader is referred to Appendix A of the report entitled "Site Selection Process, Phase 4A; Selection of Preferred Site(s), Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

8.5 GLOSSARY OF SELECTED TERMS

Sources are provided at the rear of this section and are referenced by the bracketed number following each definition.

Some definitions are altered slightly to reflect useage in this report and may not reflect the wide range of meanings provided in the source.

8.5 GLOSSARY OF SELECTED TERMS

Alluvium
Sediment composed of organic material, clay, silt, sand, gravel cobbles, or boulders deposited by postglacial streams. (2)

Aquifer
A body of sediment (or rock) that contains sufficient saturated permeable material to conduct ground water and yield economically significant quantities of ground water to wells and springs.(2)

Bearing Pressure (Allowable)
Means the maximum pressure that may be safely applied to a soil or rock by the foundation unit in design under expected loading and subsurface conditions. (8)

Confining Bed (Layer)
A body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers. (1)

Darcy's Law
For the velocity of percolation of water in saturated soil: Velocity = coefficient of permeability x hydraulic gradient. (4) (hydraulic conductivity is used in place of coefficient of permeability in this report).

Desiccated Crust
The exposure of fine-grained sediments to drying is accompanied by shrinkage and possibly cracking. Precompression of the upper portions of clay layers by drying is frequently observed in many of the profiles encountered in practice. The effects of desiccation are an increase in strength and a decreased water content. (6)

Drawdown
The lowering of the water level in a well as a result of withdrawal. (1)

Drift
A general term applied to all rock material (clay, silt, sand, gravel, boulders) transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier. (1)

Evaporite
A nonclastic sedimentary rock composed primarily of minerals produced from a saline solution as a result of extensive or total evaporation of the solvent. Examples include: gypsum, anhydrite, rock salt, primary dolomite, and various nitrates and borates. (3)

Geometric Mean
The nth root of the product of the values of n positive numbers; the antilogarithm of the mean of the logarithms of individual values. (1)

Geotechnical, Geotechnics
Pertaining to the broad field of geotechnics. The application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust for the solution of engineering problems. (1)

Glacial Lake
A lake fed predominantly by glacial meltwater or a lake in a depression in part closed by glacial ice. Includes lakes not directly adjacent to the glacier and lakes lying against or on a glacier, and fed mainly by waters derived from the melting of a glacier. (2)

Glaciofluvial
Pertaining to streams flowing from glaciers or to the deposits made by the streams. (2)

Glaciolacustrine
Pertaining to or characterized by glacial and lacustrine (lake) conditions. Material deposited in lakes affected by glacier ice, or deposited by meltwater flowing directly from glaciers into a lake. (2)

Ground Water
Subsurface water occurring below the water table (phreatic surface) in the saturated zone in which all pores are filled with water under hydrostatic pressure. This contrasts with subsurface water above the water table, which is referred to as soil moisture. (2)

Grout
A cement slurry of high water content, fluid enough to be poured or injected into spaces and thereby fill or seal them. (1)

Hardness (Water)
A property of water causing formation of an insoluble residue when the water is used with soap, and forming a scale in vessels in which water has been allowed to evaporate. It is primarily due to the presence of ions of calcium and magnesium, but also to ions of other alkali metals, other metals (e.g. iron), and even hydrogen. Hardness of water is generally expressed as parts per million as $CaCO_3$ (40 ppm Ca produces a hardness of 100 ppm as $CaCO_3$); also as milligrams per litre, and is the combination of carbonate hardness and noncarbonate hardness. (1)

Hazardous Waste
Waste that poses a present or potential danger to human beings or other organisms because it is toxic, flammable, radioactive, explosive, or has some other property that produces substantial risk to life. (1) (Use here excludes radioactive waste)

Heave
A predominantly upward movement of a surface, caused by expansion or displacement, as from swelling clay, removal of overburden, seepage pressure, or frost action. (1)

Hydraulic Gradient
In an aquifer, the rate of change of total head per unit of distance of flow at a given point and in a given direction. (1)

Hydraulic Head
The height of the free surface of a body of water above a given subsurface point. (1)

Hydraulic conductivity
The proportionality factor in Darcy's law as applied to the viscous flow of water in soil, that is, the flux of water per unit gradient of hydraulic potential. (3)

Hydrogeology
The science that deals with subsurface waters and with related geologic aspects of surface waters. (1)

Hydrostratigraphic Unit
A term proposed by Maxey (1964, p. 126) for a body of rock having considerable lateral extent and composing "a geologic framework for a reasonably distinct hydrologic system". (1) (used here for soil and rock).

Infiltration
The flow of a fluid into a solid substance through pores or small openings; specifically the movement of water into soil or porous rock. (1)

Lamina
The thinnest recognizable unit layer of original deposition in a sediment or sedimentary rock, differing from other layers in colour, composition, or particle size; specifically such a sedimentary layer less than 1 cm in thickness (commonly 0.05-1.00 mm thick). (1)

Log
A continuous record as a function of depth, usually graphic and plotted to scale on a narrow paper strip, of observations made on the rocks and fluids of the geologic section exposed in a well bore. (1) (used here for soil and rock).

Moraine
Accumulation of glacial material (mainly till) deposited by glaciers. (2)

Particle Size Classification System (9)

Name	Qualifying Term	Approximate Particle Size (mm)
Boulders		>200
Cobbles		60-200
Gravel	(Pebble)	2-60
Sand	Coarse	0.6-2
	Medium	0.2-0.6
	Fine	0.06-0.2
Silt		0.002-0.06
Clay		<0.002

Permeability
The capacity of a porous medium to transmit a liquid or gas subjected to an energy gradient (in the case of water, hydraulic gradient). (2)

Porosity
The ratio of the volume of voids to the total volume of a soil sample. (4). Effective porosity is the amount of interconnected space available for fluid transmission (3).

Quaternary
The youngest period of the two geologic time divisions of the Cenozoic Era. The Quaternary is subdivided into the Pleistocene and Recent (or Holocene) Epochs. It comprises all geologic time and deposits from the end of the Tertiary (approximately 2 million years ago) until and including the present. (2)

Saturated
Said of the condition in which the interstices of a material are filled with a liquid, usually water. It applies whether the liquid is under greater than or less than atmospheric pressure, so long as all connected interstices are full. (1)

Settlement
Downward movement of a structure such as a railway bridge, dam, or building, due to compression or movement of the soil below it. (4)

Shear Strength
The internal resistance offered to shear stress. It is measured by the maximum shear stress, based on original area of cross-section, that can be sustained without failure. (5)

Two extreme conditions may be recognized: drained conditions, under which the changes in stress are applied so slowly with respect to the ability of the soil to drain that no excess pore pressures develop, and undrained conditions, under which the stresses are changed so rapidly with respect to the ability of the soil to drain that no dissipation of pore pressure takes place. (7)

Slug Test
A method of determining in situ hydraulic conductivity in a single piezometer by causing an instantaneous change in the water level by adding or displacing a known volume of water. (10)

Split Spoon Sampler
Sampling spoons for exploratory borings commonly consist of a pipe with an inside diameter of about 35 mm and an outside diameter of about 51 mm. The pipe is split lengthwise. Consequently the sampler is called a split spoon. While the sample is being taken, the two halves of the spoon are held togther at the ends by short pieces of threaded pipe. One piece serves to couple the spoon to the wash pipe. The other, which has been sharpened, serves as the cutting edge while the spoon is driven into the soil. Exact dimensions are designated in ASTM DI586-67. (7)

Static (Water) Level
That water level of a well that is not being affected by withdrawal of ground water. (1)

Stratigraphic Unit
A stratum or body of adjacent strata recognized as a unit in the classification of a rock sequence with respect to any of the many characters, properties, or attributes that rocks may possess. (1)

Surcharge Load
A weight per unit of area of fill great enough to consolidate the soil sufficiently to increase its strength or reduce its compressibility to the required extent within the time available. Compressible soils such as clays, loose silts, and most organic soils may be compacted by surcharging. (7)

Till
An unsorted mixture of clay, silt, sand, pebbles, cobbles and boulders deposited directly by glacier ice. (2)

Water Table
A surface in the saturated zone below ground level along which the hydrostatic pressure is in equilibrium with the atmospheric pressure. (2)

Weathering
The destructive process or group of processes by which earthy and rocky materials on exposure to atmospheric agents at or near the earth's surface are changed in colour, texture, composition, firmness, or form with little or no transport of the loosened or altered material; specifically, the physical desintegration and chemical decomposition of rock that produce an in situ mantle of waste and prepare sediments for transportion. (1)

SOURCES

(1) Glossary of Geology (Second Edition); R.L. Bates and J.A. Jackson; American Geological Institute, Falls Church, Virginia, 1980.

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(6) Fundamentals of Soil Behaviour; J.K. Mitchell; John Wiley and Sons Inc., 1976.

(7) Soil Mechanics in Engineering Practice; K. Terzaghi and R.P. Peck; John Wiley and Sons, 1967.

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(9) Bulletin of the International Association of Engineering Geology; (Symposium on Engineering Geological Problems of Construction on Soluble Rocks; Istanbul, Turkey, Sept. 14-18, 1981); Published by the International Association of Engineering Geology.

(10) Groundwater; J.A. Cherry and R.A. Freeze; Prentice Hall Inc., New Jersey, 604 p.

8.6 DETAILED FIELD METHODS

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8.6.1 INTRODUCTION

Field data for of the Phase 4A hydrogeologic onsite investigations were collected in a standardized fashion and formed part of the basis for geologic, hydrogeologic, and geotechnical comparisons of the eight candidate sites. An outline of the major field activities is shown in Figure 9. The study approach was modified only slightly on a site-by-site basis to accommodate differing circumstances and site conditions. Standard procedures for the drilling and sampling operations, as outlined in the Gartner Lee Associates Ltd. "Drilling and Sampling Protocol" document (GLAL 1984a), were adhered to throughout the drilling program. This protocol document provides examples of field forms used to document field activities and should be referred to for more detailed drilling and sampling procedural descriptions.

8.6.2 DRILL SITE IDENTIFICATION

8.6.2.1 Preliminary data analysis

A preliminary review of existing water well and test hole data was completed to establish a basis for the selection of tentative drill locations. Criteria used included the following:

- the distribution of existing test holes and water wells;
- the continuity of existing data; and
- anomalous or unusual site conditions.

While locations were selected primarily on technical grounds, practical considerations such as site access, potential crop damage, and landownership were also taken into account.

DETAILED FIELD METHODS

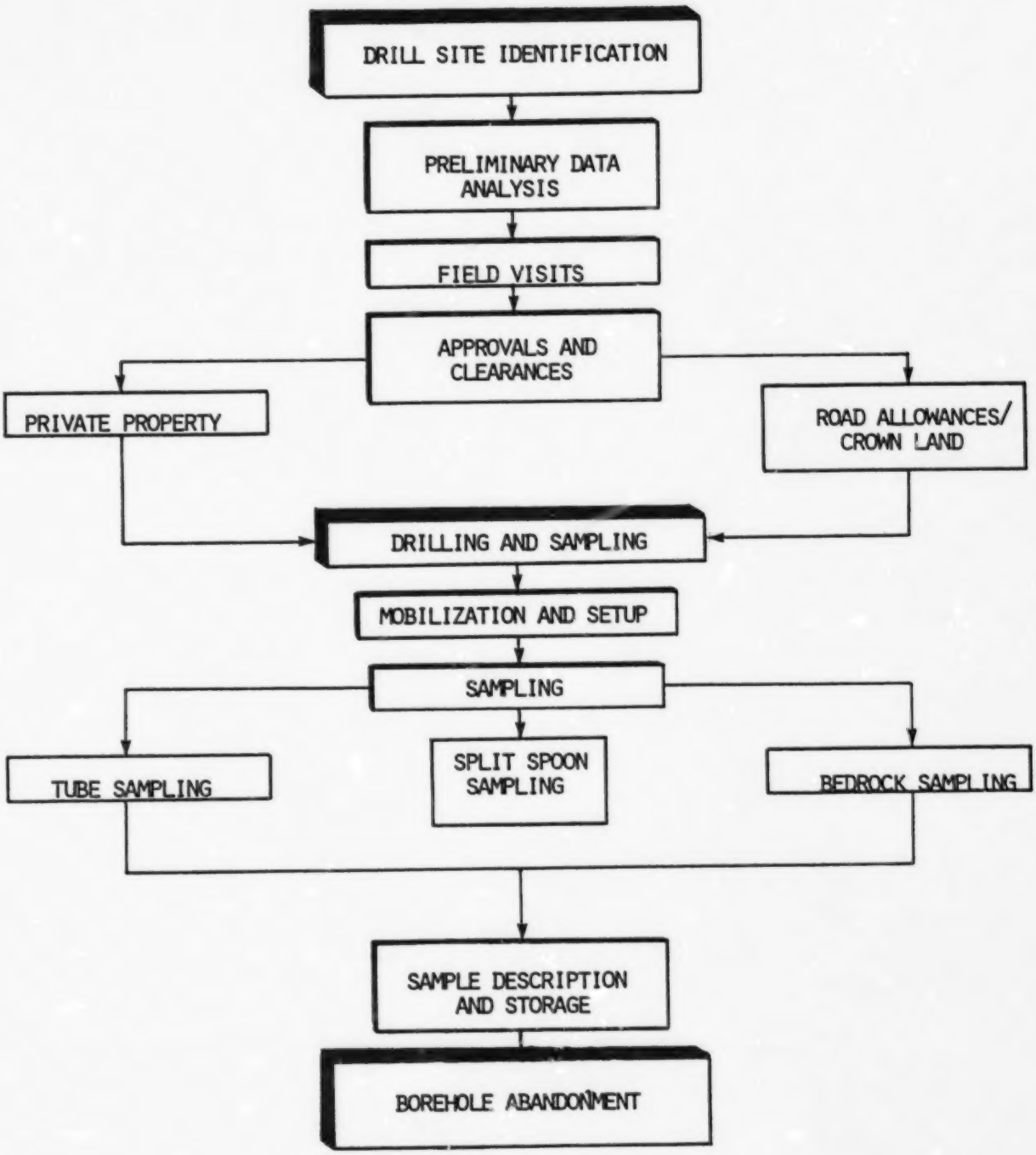


Figure 9

8.6.2.2 Field visits

The concerns of local public interest groups and individuals were also considered in selecting drill locations. Local interest groups were invited to participate during field checking of the drill locations. During these field visits, additional data on water use, local soil conditions, and wells were obtained from local residents. This information was used as a check on some of the field data obtained previously by Ecolgistics Limited during the 1984 "Walk and Talk" survey. The amount of information thus obtained varied from site-to-site and depended largely upon the degree of co-operation given by residents and landowners.

A limited amount of soil probing was completed at Candidate Sites LF-3C, LF-9C, and PI-13N using a 25 mm (1 inch) magnesium hand auger. These investigations were generally limited to a depth of 1 to 2 m. Hand augering was directed toward areas of suspected granular soils or anomalous soil conditions identified by local residents. Soil probing was confined to areas where property access was permitted. Soil descriptions are included under "Field Station Descriptions" in the individual technical site reports.

The tentative drill locations were adjusted during the field visits to avoid difficult or unsafe drilling locations. Each location was marked with a temporary wooden stake. Final adjustments were subsequently made, where necessary, to provide the required safe setbacks from buried and overhead services.

8.6.2.3 Approvals and Clearances

Clearances for both road allowances and adjacent private

or public property were pursued where identified drilling locations were located in the vicinity of local roads. Road allowances were drilled where access to private property was denied.

Landowners and tenants of affected properties were initially contacted by GLAL and verbal approval for test drilling was obtained. Approval was confirmed with a follow up letter from OWMC. For road allowance clearances, the appropriate agencies were contacted and the necessary permit approvals were obtained.

Utilities were contacted and buried service cables and/or pipes were field located by utility personnel and final adjustments of drill locations were completed. Drilling approvals and clearances were completed on a site-by-site basis.

8.6.3 DRILLING AND SAMPLING

8.6.3.1 Drilling equipment and setup

All Terrain Drilling Limited was retained to provide drilling services. The drilling equipment included truck and track mounted CME 75 auger drilling rigs. Two rigs were used simultaneously for most of the drilling program. Each rig was equipped to drill and sample both soils and bedrock. Each rig was staffed with a three man drilling crew and supervised by a GLAL geologist. The drilling program was initiated on August 13, 1984 at Site LF-3C and was completed on November 22, 1984 at Site LF-4N.

The drill rigs were set up in accordance with standard drilling practices and in a manner that allowed the safe

and efficient operation of the equipment. A safety corridor was roped-off around the drill rig to limit access to the rigs. Access to the roped-off area was restricted to individuals with proper safety equipment which included steel-toed boots and a hard hat. A record was kept of all visitors to the drill site as well as persons entering the roped-off area.

Sample documentation and storage facilities were set up at the edge of the roped-off area by GLAL. Soil and rock samples were accessible to the general public for viewing and/or photographing as the samples were being logged by the onsite geologists. Samples were subsequently sealed in tubes or core boxes, labelled, and placed in storage. On several occasions, soil sample tubes were re-opened for examination at the request of local residents.

8.6.3.2 Soil sampling

The drilling program was designed to obtain a continuous column of soil from the ground surface to and including the upper few metres of the underlying bedrock. Soil samples were obtained using hollow stem auger drilling techniques. Hollow stem augers (108 mm (4.25 inch) inside diameter) were used throughout the drilling program.

Split tube sampling. Tube samples measuring approximately 89 mm (3.5 inches) in diameter by 1.52 m (5 ft.) in length were taken continuously from ground level to the bedrock surface. The tube sampler consisted of a split tube with a bevelled sampler tip. The split tube was threaded at both ends and fastened to the drill rods as shown in Figure 10. The sampler as advanced inside the hollow stem augers with

Continuous Soil Sampling With Split Tube Sampler

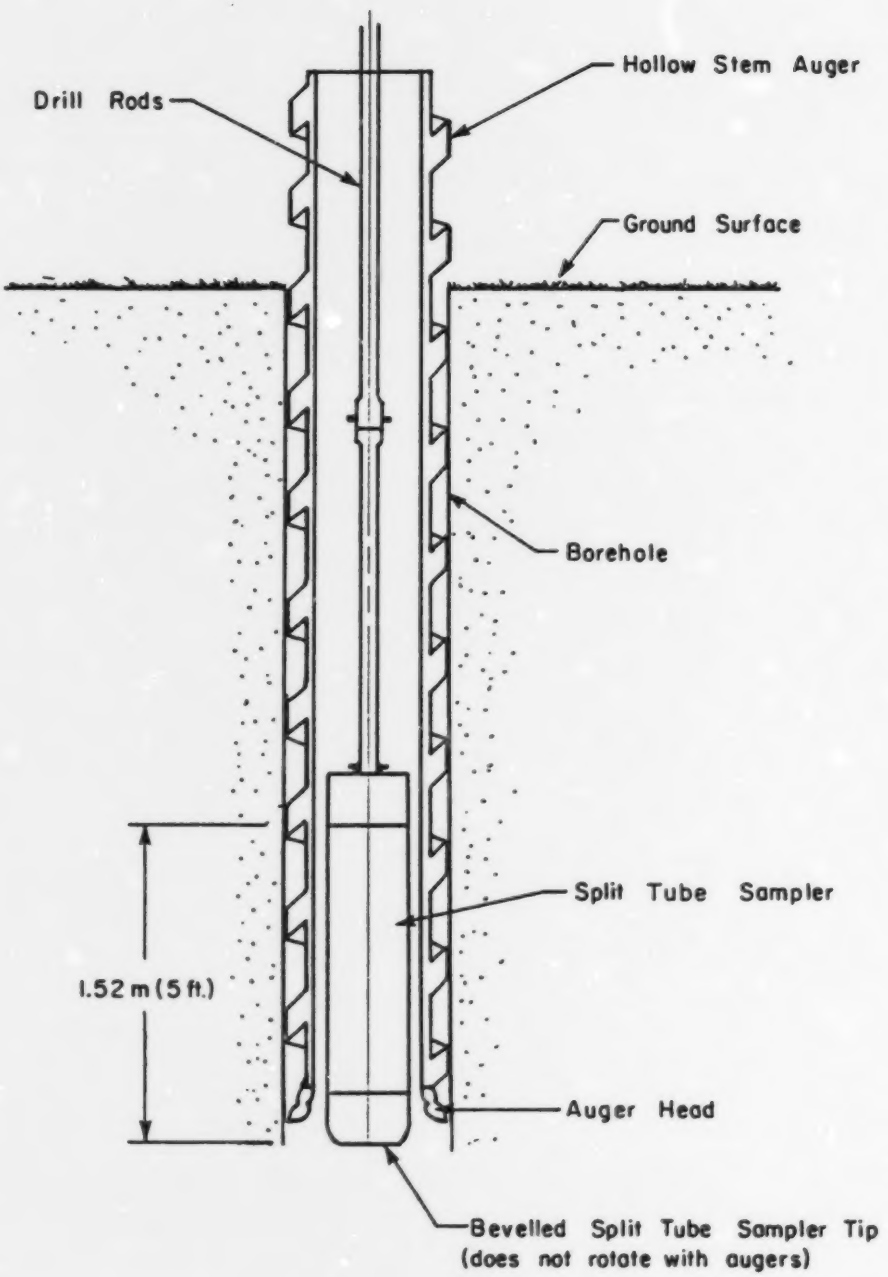


Figure 10

the bevelled tip slightly ahead of the cutting edge of the augers. A split tube sample was obtained by advancing the sampler with the rotating augers. The augers and sampler were advanced at about 1.52 m (5 ft.) intervals or until refusal, and the sampler was then withdrawn from the borehole. The soil sample was removed from the tube and the sampler washed with clean water. Sample recovery for the tube samples was generally between 90 to 100% and was recorded in the field log. Difficult drilling conditions or large cobbles occasionally resulted in lower sample recovery.

Split spoon sampling. Standard split spoon samples were taken at about 1.52 m (5 ft.) intervals throughout the soil sequence overlying bedrock and beginning at about 1.52 m 5 ft.) from the ground surface. Sample intervals are shown schematically in Figure 11.

The split spoon sampler was driven by dropping a 63.5 kg (140 lb.) weight a distance of about 750 mm (30 inches). The sampler was inserted inside the hollow stem augers in a similar fashion to the tube sampler. It was then driven into the soil below the bottom of the augers a distance of about 460 mm (18 inches) or until refusal. The number of blows required to advance the sample for each interval of about 150 mm (6 inches) was recorded in the field log. The split spoon was usually withdrawn when 50 or more blows were required to advance the sampler approximately 150 mm (6 inches) into the subsoil.

Standard split spoon samples were obtained in place of tube samples where difficult drilling conditions were

Soil & Rock Sample Intervals, Phase 4A Drilling Program

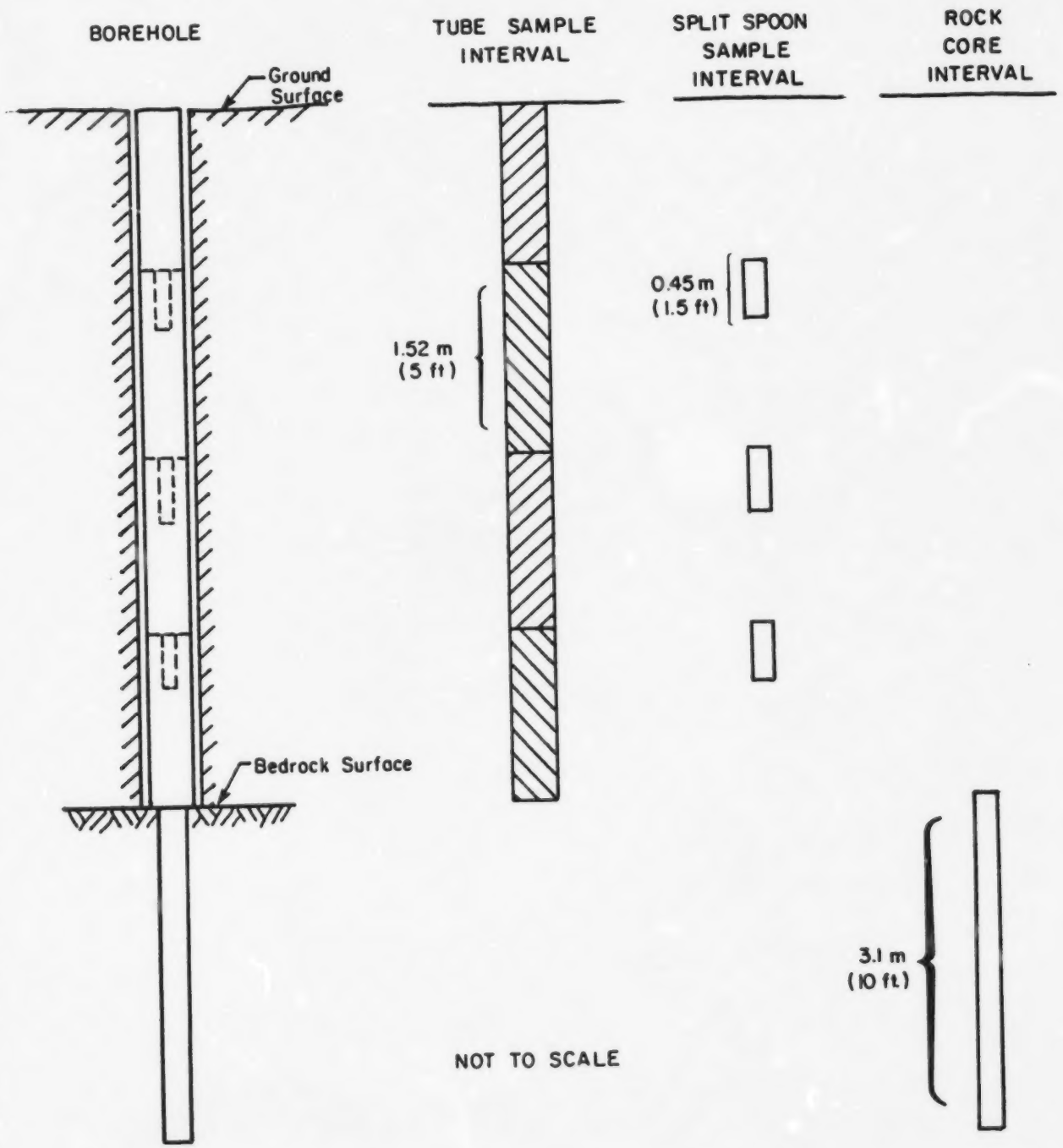


Figure 11

encountered. At Site LF-4N, Borehole 4, granular soils were encountered at a depth of about 30 m (100 ft.) causing refusal of the tube sampler. Standard split spoon samples were taken from a depth of 30 m (100 ft.) at intervals of 0.5 to 3 m (1.6 to 9.8 ft.) to a depth of about 40 m (130 ft.). Difficult soil conditions were also encountered at Site LF-2N, Borehole 1. Numerous rock fragments were encountered below a depth of about 12 m (40 ft.) at this location. Split spoon samples at 0.76 m (2.5 ft.) intervals were taken between depths of about 12 m (40 ft.) to 34 m (110 ft.).

Difficult (sandy and gravelly) soil conditions at Site PI-27E, Borehole 3 prevented tube sampling between depths of about 16 to 30 m (50 to 100 ft.). Similar fine, sandy soils were also encountered in Borehole 4 at this site at depths between approximately 24 to 30 m (80 to 100 ft.). Standard split spoon samples at 1.5 m (5 ft.) intervals were collected over these intervals at these two borehole locations.

Moisture tin samples. A small soil sample of approximately 100 grams was taken from the tip of each split spoon sample for laboratory determination of the soil moisture content. Soil moisture samples were placed in air tight tins immediately after they were taken from the split spoon samples. The moisture tin (sample) numbers were recorded on the field borehole logs. The samples were temporarily stored in the field and shipped in batches to the GLAL office for transfer to a commercial laboratory.

Rotary drilling. Rotary drilling techniques were occas-

ionally used to penetrate difficult soils that could not readily be drilled with conventional hollow stem auger drilling methods. These techniques were also used where granular soils, acting under hydraulic pressures, were forced up inside the hollow stem augers. This condition prevented the split tube and split spoon samplers from passing through the plugged portions of the hollow stem augers. Clean water or a water/bentonite mixture was circulated through a rotating tricone drill bit to clean out the material in the hollow stem augers. Rotary drilling was also used to drill through gravelly or bouldery soils such as those encountered at depth at Site LF-4N, Borehole 4, and at Site LF-2N, Borehole 1.

8.6.3.3 Bedrock sampling

Boreholes were generally completed into bedrock except in a few cases where difficult drilling conditions were encountered and the borehole was terminated before reaching bedrock.

The bedrock contact was often obscured as a result of weathering, particularly in shale. Under conditions of extreme weathering, shale was occasionally retrieved within the split tube and split spoon samplers. For example, a nearly complete 1.5 m core of weathered bedrock was obtained in the split tube sampler in Borehole 5 at Site PI-13N.

Diamond drill coring. Most bedrock samples were obtained using a diamond drill bit and NX size core barrel. Rock core samples generally measured about 53 mm (2.1 inches) in diameter and up to 3 m (10 ft.) in length. The diamond drill bit and core barrel were positioned on the bedrock

surface from inside the hollow stem augers. A rock core was obtained by the cutting action of the rotating drill bit. Clean water was circulated in the borehole to remove cuttings from around the drill bit. The water used in this operation was field checked with a Hach Kit for chlorides and sulphates to ensure compatibility with grouting materials used for borehole abandonment. The amount of water used was recorded on the field logs.

Bedrock coring was terminated when a sufficient length of sample was retrieved to prove-out the bedrock contact. The bedrock core recovered varied in length from about 1.5 m to 3 m (5-10 ft.) between borehole locations.

8.6.3.4 Sample description and storage

Soil and rock samples, taken from the boreholes, were described in detail in the field and photographed. Sample descriptions were recorded on the Field Borehole Log forms. These logs, together with the sample photos, form a permanent record of the sampling procedures.

The tube samples were transferred directly from the sampler into PVC tubular piping which was cut in half. The PVC pipe measures 89 mm (3.5 in.) inside diameter by 1.5 m (5 ft.) long. One 'side' of the sample was scraped clean along its length with a knife or spatula to facilitate sample description. Individuals and local interest groups were allowed to view the samples and make their own field notes of the samples. Soil scrapings were given to those interest groups that requested them or else were discarded. Soil samples were sealed in the PVC tubes by covering the

ends with plastic caps and taping the entire tube along the seams. Sample labels were affixed to each PVC tube.

The samples were stored temporarily in a field van until a sufficient number of samples were obtained for transport to permanent storage facilities in Toronto at the Ontario Geological Survey. Each shipment of samples were itemized on a Sample Packing list. The contents of each shipment were also recorded on a Chain of Custody Record which showed the times and dates of sample transfer as well as the individuals involved in handling the samples.

Split spoon soil samples taken during the project were described in the field and soil moisture (moisture tin) samples taken from the base of the split spoon sampler were submitted to a laboratory for analysis. The moisture tin number was recorded on the Field Borehole Log and on the Sample Packing List. In cases where a split spoon sample was taken in place of the larger split tube samples, they were stored in labelled plastic bags and retained with the other samples. The top of each bedrock core segment was marked on both the core boxes and on the rock core itself with a felt marker.

The soil and rock samples were re-examined by a senior GLAL geologist at the permanent storage area at the Ontario Geological Survey. The field descriptions were combined with the more detailed geologic log prepared by the senior geologist to compile a final borehole log. All soil samples were resealed after examination.

8.6.4 BOREHOLE ABANDONMENT

Boreholes were generally terminated after pentrating the bedrock or when difficult conditions prevented further drilling. An exception to this occurred at Site LF-1E, Borehole 3, where a gas pocket was encountered at a depth of about 17.8 m (58 ft.) in the drift. The borehole was terminated at this depth and sealed as soon as the gas pressure subsided sufficiently to allow grouting.

8.6.4.1 Grouting

On completion of each borehole all sampling equipment and temporary casing were removed from the borehole. Each borehole was then filled to the surface with a cement/ bentonite slurry. This was accomplished by injecting grout through the hollow stem augers as they were slowly withdrawn from the hole as shown in Figure 12. Specifications of the slurry mix, as set out in the Drilling and Sampling Protocol Document (GLAL 1984a) were altered slightly to accommodate site conditions. The actual grout slurry mix is compared on a percent weight basis to the specified grout slurry mix below:

Specified Grout Slurry	Actual Grout Slurry
1.2% Bentonite	2-3% Bentonite
6.0% Hydrated Lime (optional)	
59.6% Cement (Portland Type 10)	40-60% Cement (Portland Type 10)
33.2% Water	37-58% Water

The increased amount of bentonite provides a more effective seal in water bearing formations. The bentonite also acts as a 'plasticizing' agent and eliminated the need

Grouting Of Borehole

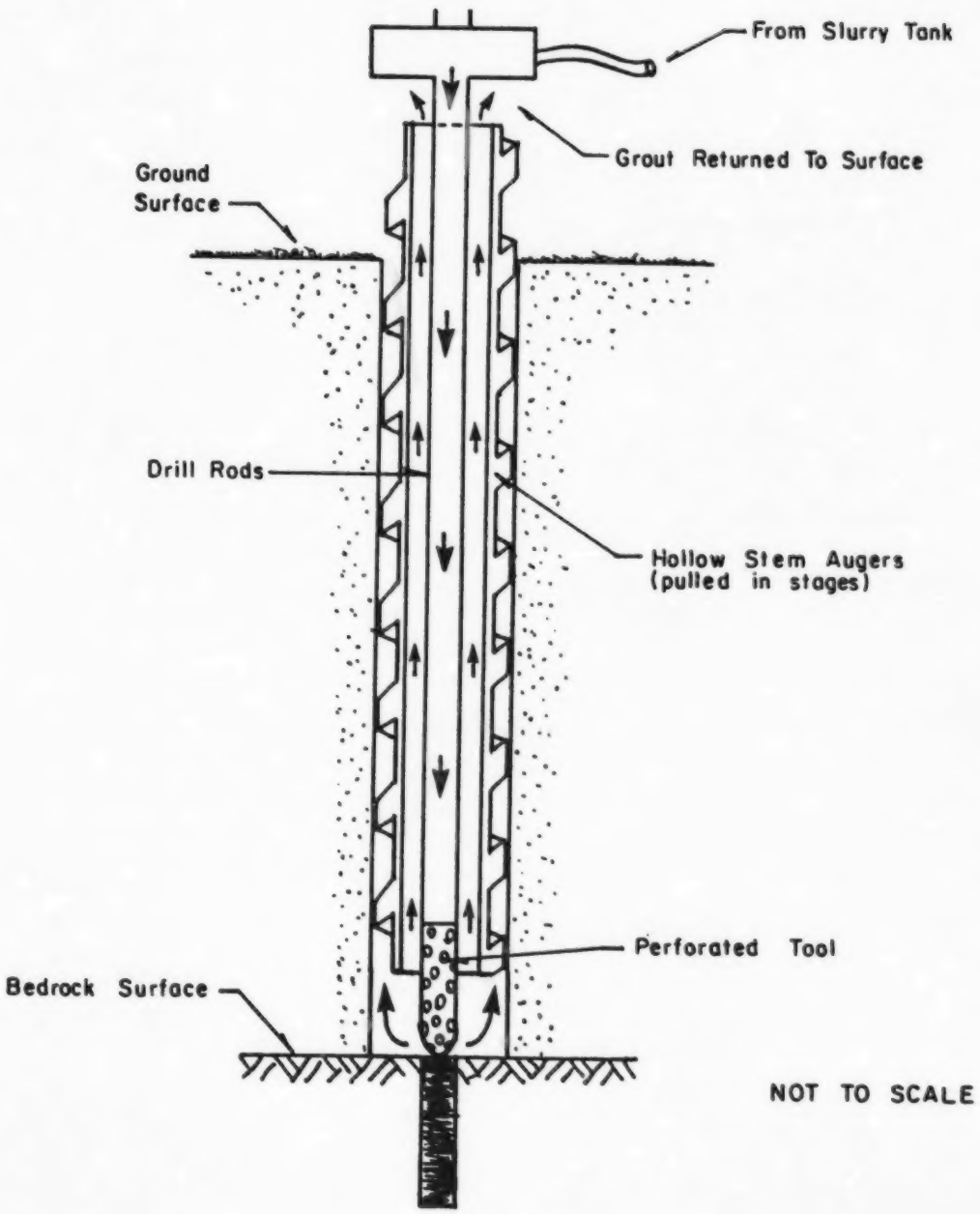


Figure 12

to add hydrated lime to the grout slurry mix. A cement mix containing slightly less than the amount of cement specified in the protocol was found to be adequate. A small sample of grout slurry was taken from each hole to confirm the setting characteristics of the mix.

The water used in the grout slurry was obtained locally and was tested wth a Hach Kit for sulphate and chloride content. Details of each grout mix were recorded on the Borehole Plugging Plan/Record for each borehole.

The grout was allowed to set overnight and generally settled to within 1 to 3 m (3-10 ft.) of ground surface. The hole was subsequently backfilled to grade with soil to avoid interference with surface activities such as ploughing or maintenance along road allowances. All boreholes from this drilling program were successfully grouted.

8.6.4.2 Site cleanup

Efforts were made to restore each drill location to predrilling conditions. The ground was levelled to grade and holes or ruts made by drilling equipment were filled with soil and in some cases resodded. While attempts were made to minimize damage, this was not always possible and compensation was provided in some cases. Photographs were taken of each drill location both before and after the drilling operations and after site cleanup.

REG. RD. 22
BRONTE ROAD
BOYNE
APPLEBY LINE
BERRY ROAD
INDIAN CREEK
RATTLESNAKE POINT
CN
Lot 12 Con 1
Lot 11 Con 7
Lot 10 Con 7
Lot 9 Con 1
Lot 6 Con 2
Lot 8 Con 6
A
B
GL10 (196)
2482 (196)
GL3 (196)
6687 (197)
5013 (194)
2469 (198)
GL9 (193)
5823 (193)
GL12 (188)
GL11 (190)
GL8 (190)
5825 (188)
3312 (187)
2463 (187)
GL7 (187)
2462 (187)
2479 (185)
GL6 (186)
GL84-5(IN) (186)
GL 84-1(IN)(181)
GL 84-1(IN) (181)
4014 (181)
GL 84-2(IN)(180)
2461 (181)
5149 (181)
4587 (180)
3463 (180)
2460 (180)
GL4 (184)
GL5 (184)
GL2 (188)
GL3 (187)
GL 84-3 (188)
E2 (187)
E3 (184)
GL 17 (184)
GL 19 (183)
GLTP4 (184)
GLTP3 (184)
GL 84-2 (184)
GL 84-1 (184)
5144 (183)
5147 (183)
3202 (184)
GL 84-5 (179)
GMTC-1 (179)
4403 (181)
3253 (181)
GL 15 (183)
GL 14 (182)
GLTP1 (183)
GLTP2 (183)
GL 13 (182)
GL 30 (182)
3399 (182)
604 (183)
632 (187)
633 (188)
3065 (188)
634 (191)
635 (191)
557 (198)
2774 (200)
3534 (201)
2847 (210)
3533 (199)
3755 (207)
605 (200)

OWMC **Ontario Waste Management Corporation**

Consultant: Gartner Lee Associates Limited

Legend:

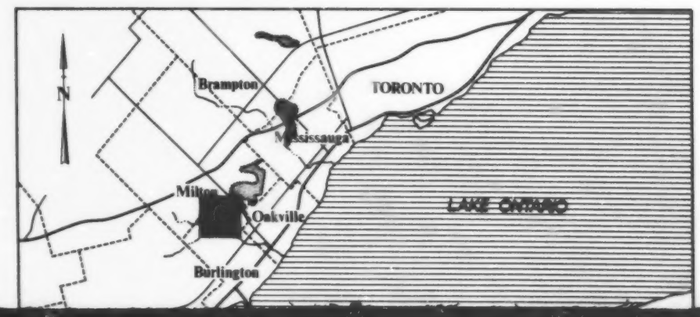
- GL 84-3 (1N) or (4N) - Gartner Lee Associates Limited borehole - 1984 - Site P1-1N or LF-4N
- GL 4 or GL-L1 - Gartner Lee Associates Limited borehole 1976 - 1979
- GLTP 1 - Gartner Lee Associates Limited Test Pit-1979
- D1 or E1 - Hydrology Consultants Limited borehole - Site P1-1N (D) or LF-4N (E)
- MB(1N)OW3 or MB(4N)OW3 - Morrison Beatty Limited borehole - Site P1-1N or LF-4N
- MTC-2 - Ministry of Transportation and Communications borehole
- 2437 - Water Well with Ministry of the Environment Number
- (183) - Estimated surface elevation in metres above sealevel
- A — A' Cross-Section

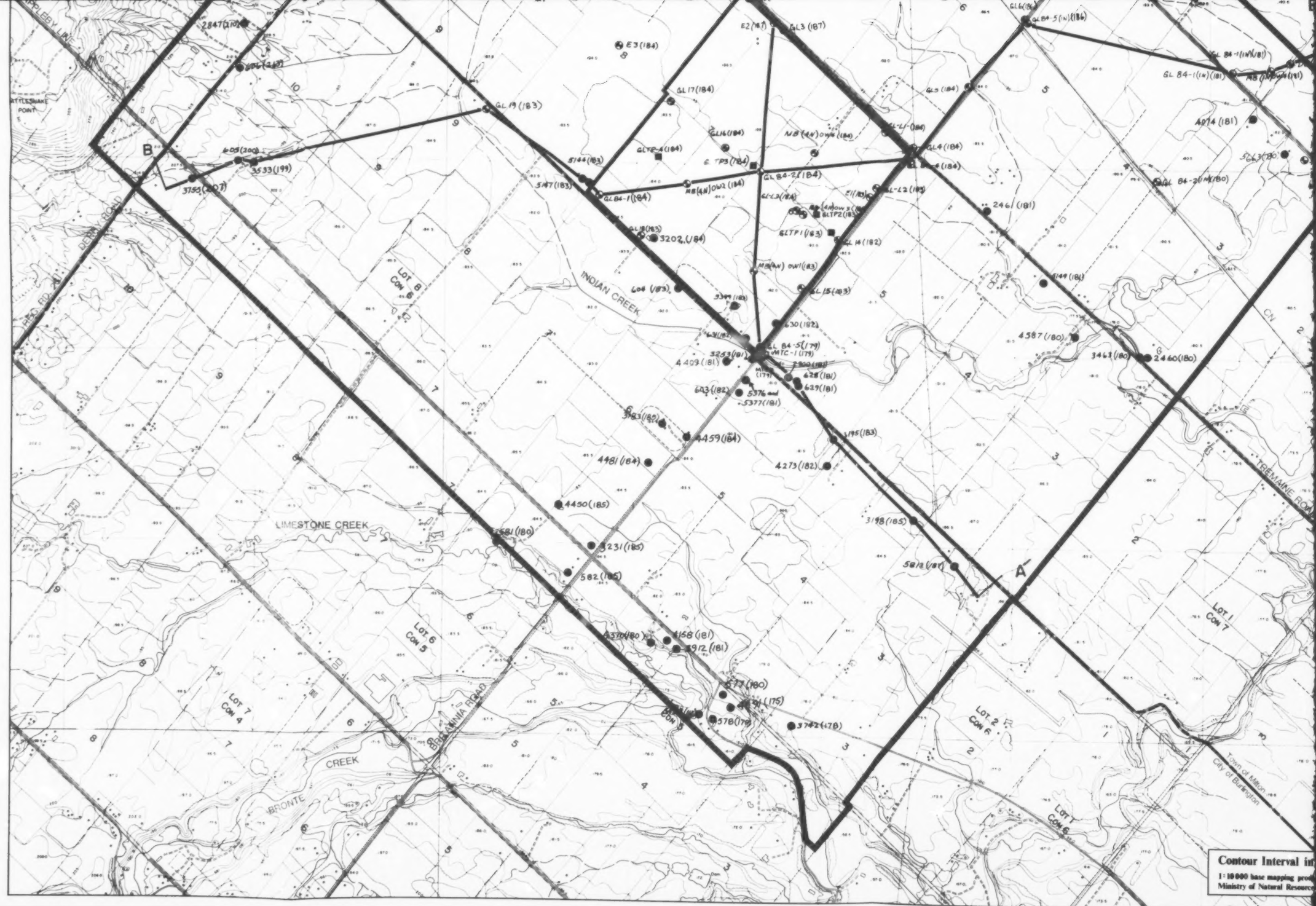
Phase 3B Acquisition Boundary **Site Vicinity Study Area Boundary**

Key Map:

LF-4 North

Lots 6 and 7; Concession VII; Town of Milton, formerly in the Township of Nelson




APPLEBY LINE
BERR ROAD
ATTLESNAKE POINT
LIMESTONE CREEK
INDIAN CREEK
BRONTE CREEK
BRONTE ROAD
TREMAINE ROAD
LOT 8 CON 6
LOT 7 CON 4
LOT 6 CON 5
LOT 2 CON 6
LOT 1 CON 7
LOT 7 CON 6
Town of Milton
City of Burlington
Contour Interval in
1:10000 base mapping pro
Ministry of Natural Resource

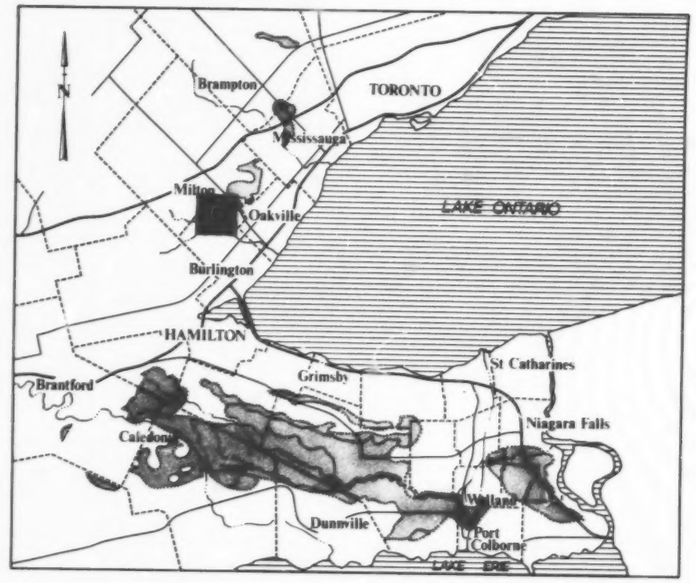
Phase 3B Acquisition Boundary

Site Vicinity Study Area Boundary

Key Map:

LF-4 North

Lots 6 and 7; Concession VII; Town of Milton, formerly in the Township of Nelson



1000 feet 0 1000

500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Well and Borehole Locations

September 1985

FIGURE 4

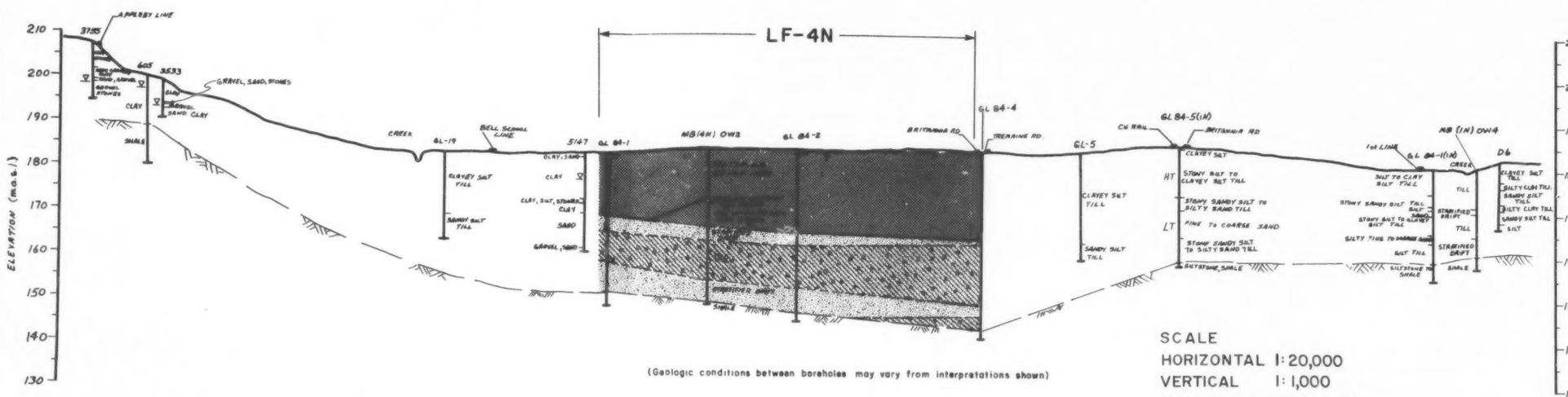
Contour Interval in Metres

1:10 000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

West
B

Looking North

East
B'



(Geologic conditions between boreholes may vary from interpretations shown)

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

Site LF-4N
CROSS-SECTION B-B'
Figure 6

LEGEND

GL 84	Gartner Lee Associates Limited Borehole 1984
GL	Gartner Lee Associates Limited Borehole 1976-1979
D	Hydrology Consultants Limited Borehole
MB (INOW	Morrison Beatty Limited Borehole
MTC	Ministry of Transportation & Communications Borehole
2437	Water Well with Ministry of the Environment Number
▽	Static Water Level in Well at Time of Construction
m.a.s.l.	Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- SILT TO CLAYEY SILT TILL (Halton Till)
- UPPER & LOWER SAND
- CLAYEY SILT TO SAND TILL & SAND INTERBEDDED (Lower Till & Sand)
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

NOTES: Consult Water Well Record Summary and Borehole Logs in Section B for detailed descriptions.

Elevations are approximate
Cross-Section Located in Figure 4

To accompany Phase 4A Technical Appendix
(Geologic Hydrogeologic and Geotechnical Considerations)

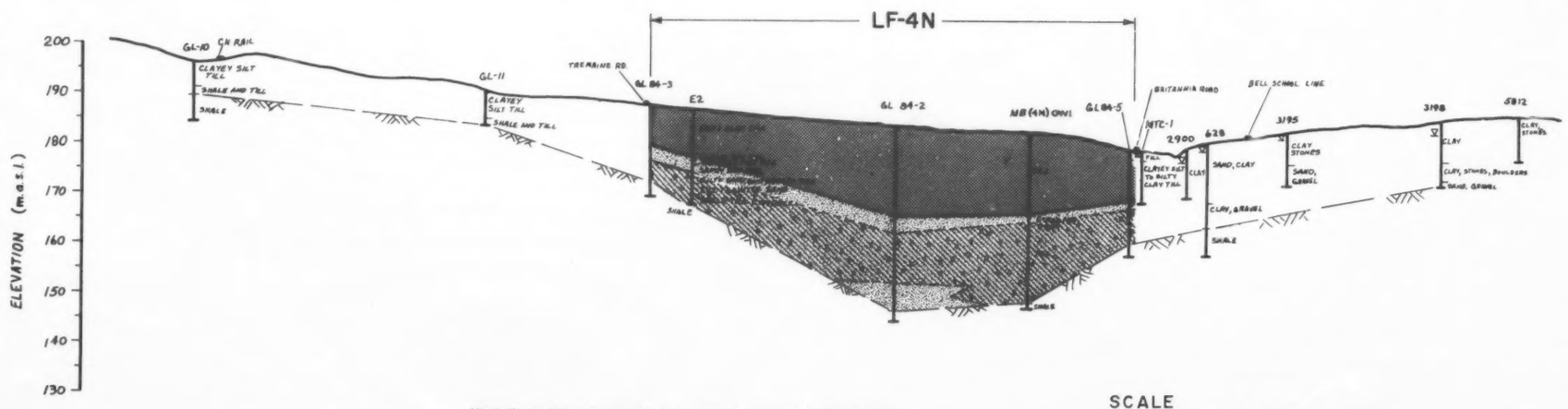
OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

North
A

Looking East

South
A'



(Geologic conditions between boreholes may vary from interpretations shown)

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

Site LF-4N
CROSS-SECTION A-A'
Figure 5

LEGEND

GL 84	Gartner Lee Associates Limited Borehole 1984
GL	Gartner Lee Associates Limited Borehole 1976-1979
E	Hydrology Consultants Limited Borehole
MB (INOW	Morrison Beatty Limited Borehole
MTC	Ministry of Transportation & Communications Borehole
2437	Water Well with Ministry of the Environment Number
▽	Static Water Level in Well at Time of Construction
m.a.s.l.	Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- SILT TO CLAYEY SILT TILL (Halton Till)
- UPPER & LOWER SAND
- CLAYEY SILT TO SAND TILL & SAND INTERBEDDED (Lower Till & Sand)
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

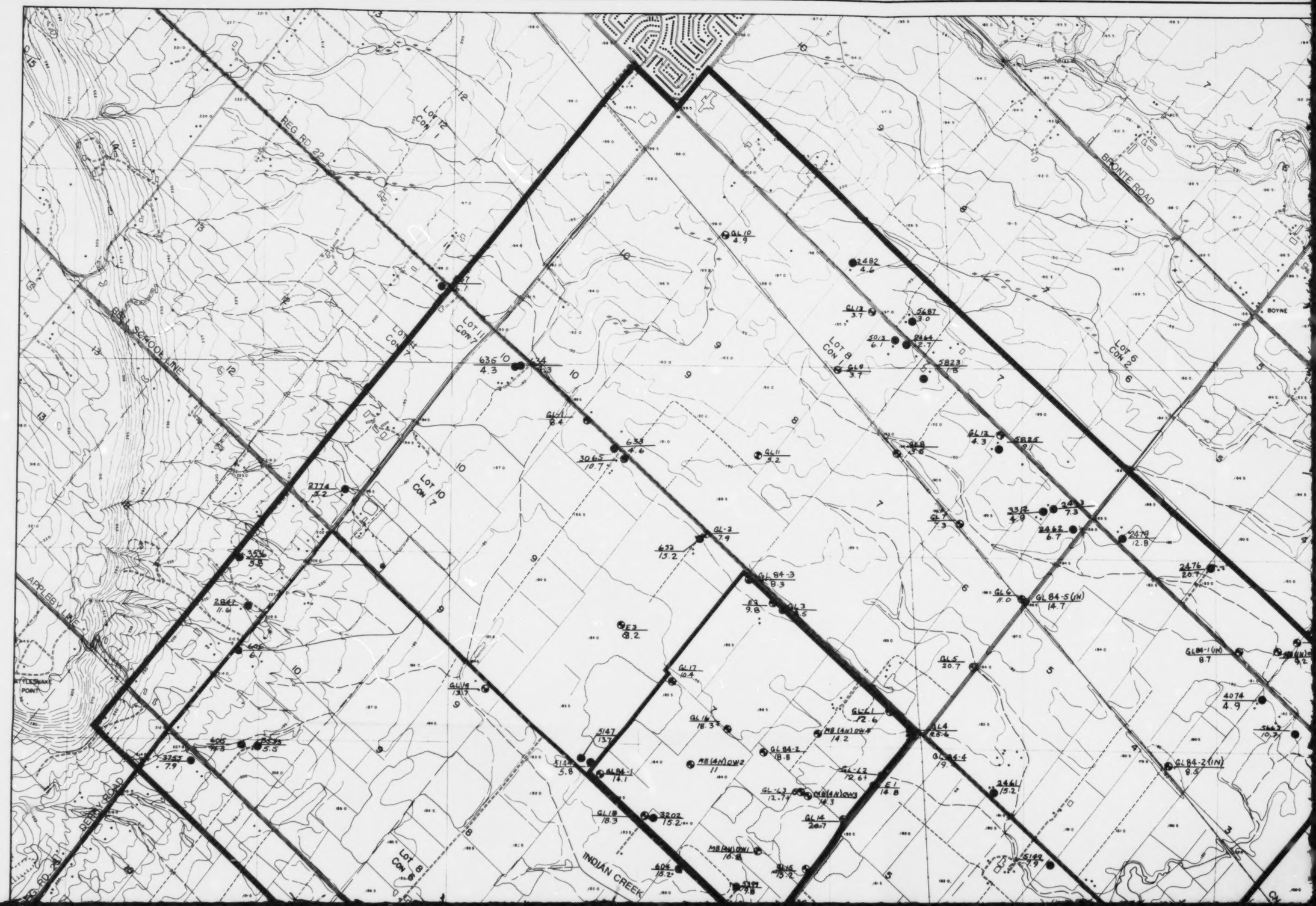
NOTES: Consult Water Well Record Summary and Borehole Logs in Section B for detailed descriptions.

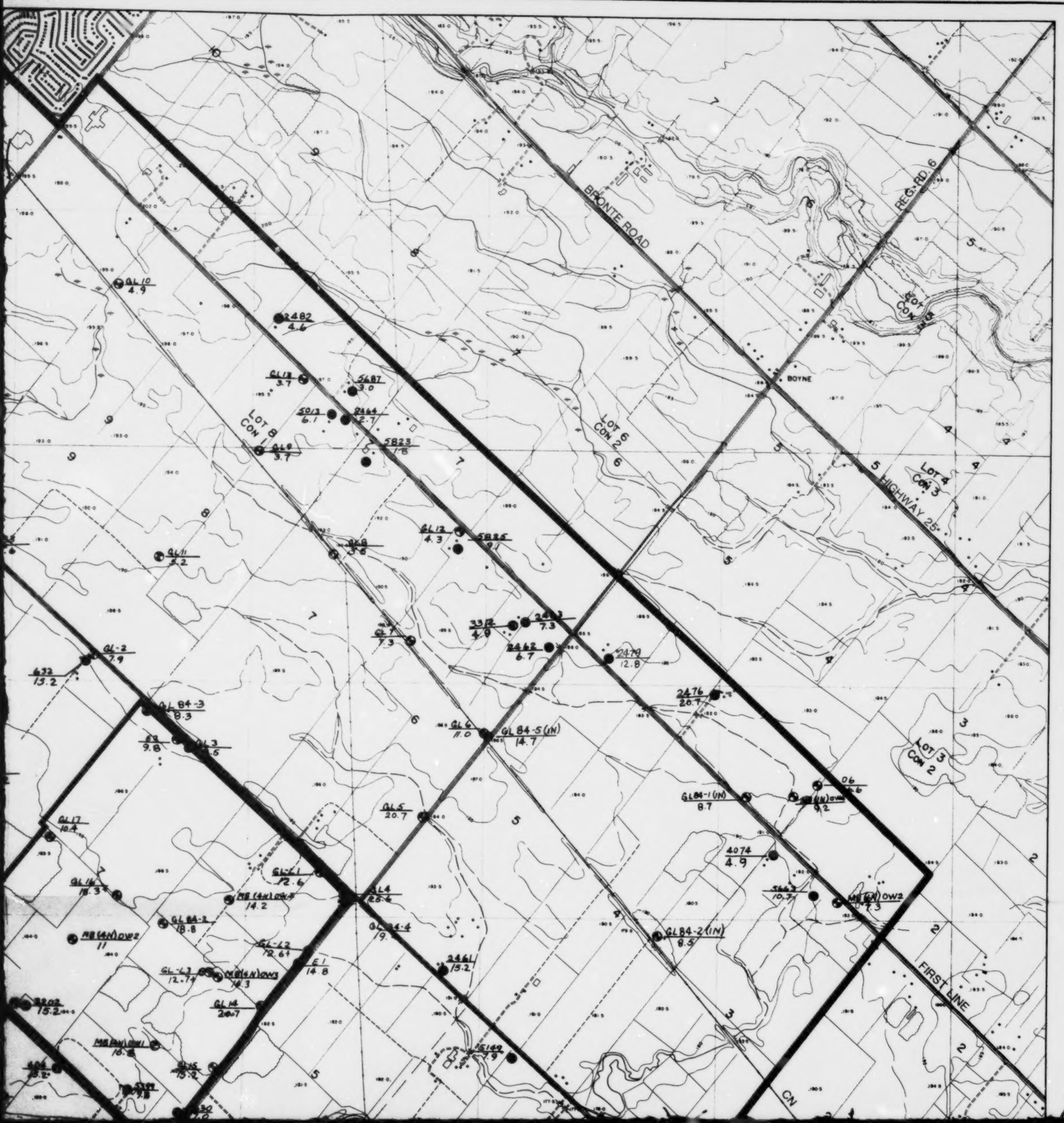
Elevations are approximate
Cross-Section Located in Figure 4

To accompany Phase 4A Technical Appendix
(Geologic Hydrogeologic and Geotechnical Considerations)

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited


REG. RD. 22
BRONTE ROAD
BOYNE
SCHOOL LANE
APPLEBY LINE
PEDDAR ROAD
INDIAN CREEK
LOT 12 CON 1
LOT 11 CON 7
LOT 10 CON 7
LOT 8 CON 6
LOT 8 CON 1
LOT 6 CON 2
GL10 4.9
2482 4.6
GL13 3.7
5687 3.0
5013 6.1
2464 2.7
5823 1.8
GL9 3.7
636 10 4.3
GL-1 8.4
633 4.6
3065 10.7
GL11 5.2
GL12 4.3
5826 9.1
GL8 3.6
GL7 7.3
3312 4.9
2463 7.3
2462 6.7
2479 12.8
2476 20.7
GL6 11.0
GL 84-5(IN) 14.7
2774 5.2
354 5.8
2847 11.4
606 6.1
GL-2 7.9
632 15.2
GL 84-3 8.3
E3 9.8
GL3 5
E2 8.2
GL17 10.4
GL5 20.7
GL84-1(IN) 8.7
GL19 13.1
5147 13.7
GL16 18.3
GL-L1 12.6
MB(4N)OW4 14.2
GL4 25.6
4074 4.9
GL84-4 19
GL84-2(IN) 8.5
GL84-1 14.1
MB(4N)OW2 11
GL84-2 18.8
GL-L2 12.6+
2461 15.2
GL-L3 12.7+
MB(4N)OW3 14.3
E1 14.8
GL18 18.3
3202 15.2
GL14 20.7
MB(4N)OW1 16.8
GL15 15.2
604 15.2
5142 7.9
3757 7.9
606 14.3
5578 5.5
5.8
TYLER SNAKE POINT



OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

- GL 84-3 (IN) or (4N) - Gartner Lee Associates Limited borehole - 1984 - Site PI-1N or LF-4N
- GL4 or GL-LI - Gartner Lee Associates Limited borehole 1976 - 1979
- D1 or E1 - Hydrology Consultants Limited borehole - Site PI-1N (D) or LF-4N (E)
- MB (IN) OW3 or MB (4N) OW3 - Morrison Beatty Limited borehole Site PI-1N or LF-4N
- 2437 - Water Well with Ministry of the Environment Number
- 14.8 Thickness of Confining Layer in Metres

Phase 3B Acquisition Boundary

Site Vicinity Study Area Boundary

Key Map:

LF-4 North

Lots 6 and 7; Concession VII; Town of Milton, formerly in the Township of Nelson

APPLEBY LINE

RATTLESNAKE POINT

REG. RD. 25

DERRY ROAD

LOT 8 CON 6

INDIAN CREEK

LIMESTONE CREEK

LOT 6 CON 5

BRITANNIA ROAD

LOT 7 CON 4

BRONTE CREEK

TREMAINE ROAD

CN

LOT 1 CON 7

LOT 2 CON 6

LOT 1 CON 6

Town of Milton
City of Burlington

Contour Interval

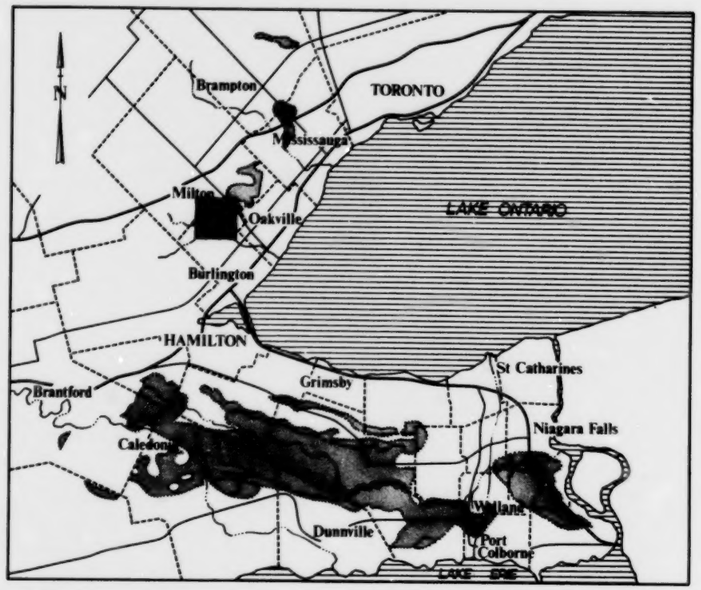
1:10 000 base mapping
Ministry of Natural Res

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map:

LF-4 North

Lots 6 and 7; Concession VII; Town of Milton, formerly in the Township of Nelson



1000 feet 0 1000
500 metres 0 500

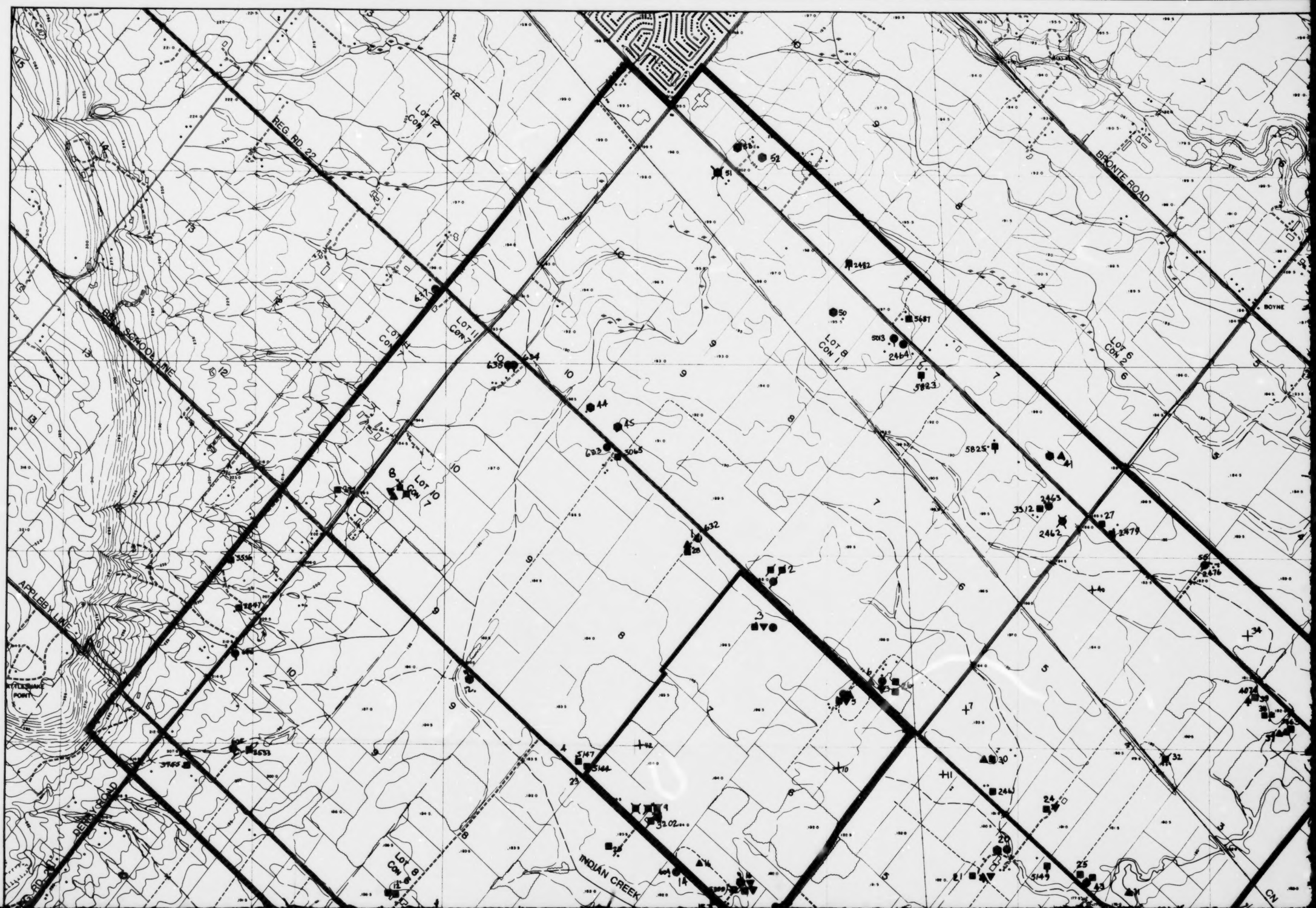
GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

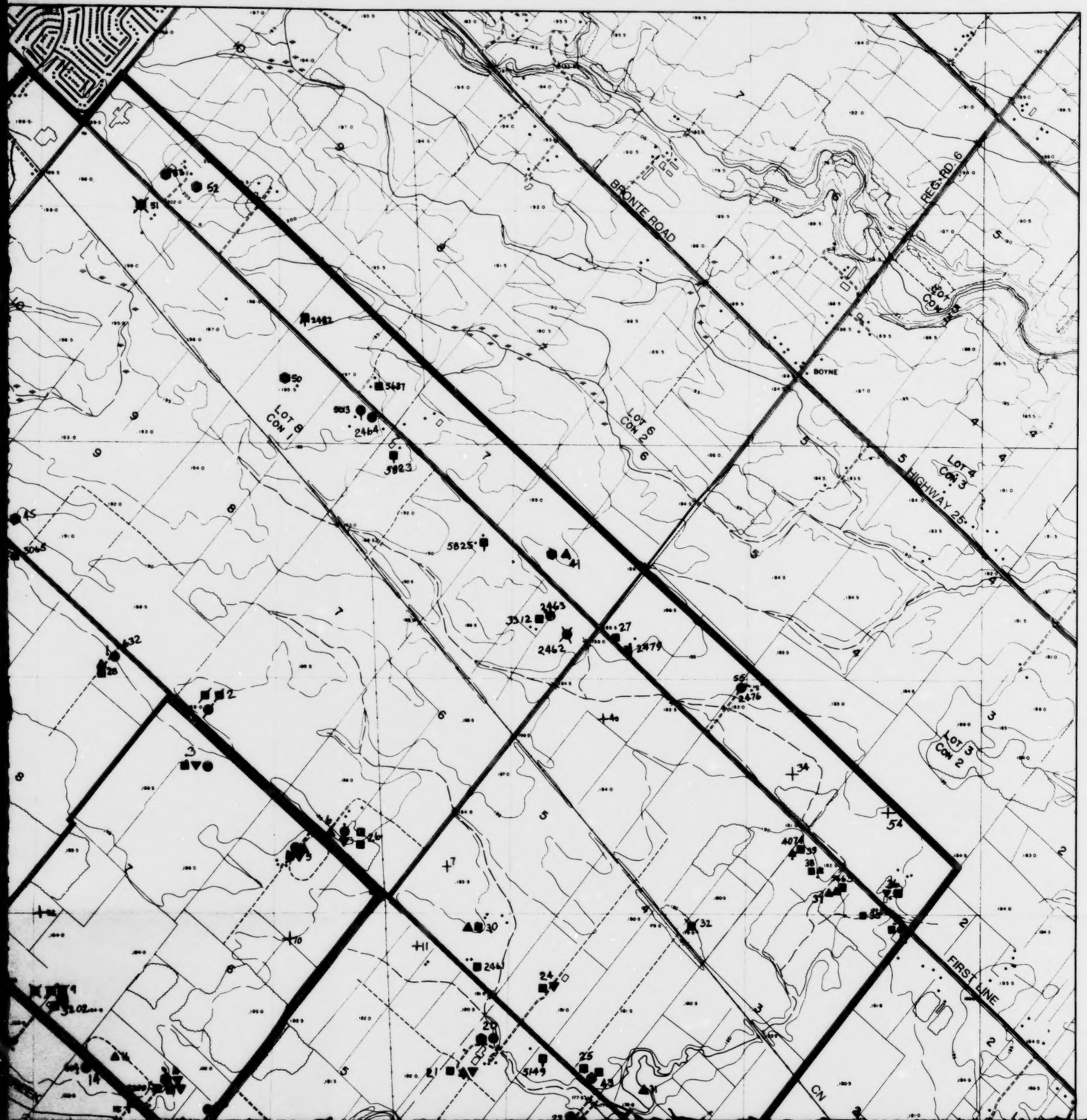
Confining Layer Thickness

September 1985 **FIGURE 7**

Contour Interval in Metres

1:10 000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984


REG. RD. 22
BRONTE ROAD
BOYNE
APPLEBY LINE
INDIAN CREEK
LOT 12 CON I
LOT 11 CON I
LOT 10 CON I
LOT 9 CON I
LOT 8 CON I
LOT 6 CON 2
CN



OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

- ● , ● DRILLED WELL COMPLETED IN OVERBURDEN, BEDROCK
- ■ , ■ DUG OR BORED WELL COMPLETED IN OVERBURDEN, BEDROCK
- ● UNKNOWN WELL TYPE
- / , X UNUSED, ABANDONED WELL
- ▲ DUGOUT OR POND
- ▼ CISTERN
- \+ ADDITIONAL FIELD INFORMATION

NOTES:

No. 1-55 FIELD INTERVIEW INFORMATION: SEE SECTION 8.2 FOR DATA

No.'s >55 MINISTRY OF THE ENVIRONMENT WATER WELL RECORD NO.; SEE SECTION 8.1 FOR DATA

Phase 3B Acquisition Boundary **Site Vicinity Study Area Boundary**

Key Map:

LF-4 North

Lots 6 and 7; Concession VII; Town of Milton, formerly in the Township of Nelson

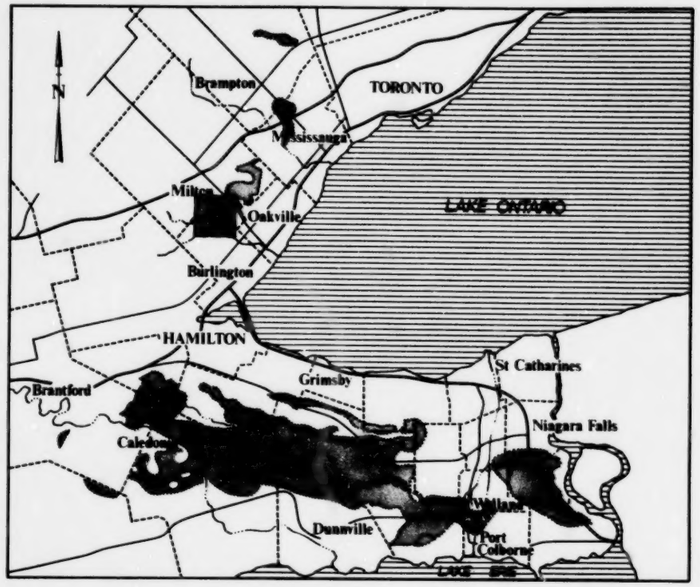
APPLEBY LINE
RYCKMANS POINT
BERRY ROAD
REG. RD. 25
Lot 8 Con 6
INDIAN CREEK
LIMESTONE CREEK
Lot 6 Con 5
Lot 7 Con 4
BRITANNIA ROAD
BRONTE CREEK
Lot 1 Con 7
Lot 2 Con 6
Lot 1 Con 6
CN
TREMAINE RD.
Town of Milton
City of Burlington
Contour Interval

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map:

LF-4 North

Lots 6 and 7; Concession VII; Town of Milton, formerly in the Township of Nelson



1000 feet 0 1000

500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Ground Water Use

September 1985

FIGURE 8

Contour Interval in Metres

1:10 000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

Number/
Numéro

6

SITE SELECTION PROCESS - PHASE 4A

TECHNICAL APPENDIX PI-27E

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS

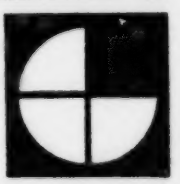
A REPORT PREPARED FOR
THE ONTARIO WASTE MANAGEMENT CORPORATION
BY
GARTNER LEE ASSOCIATES LIMITED

THIS REPORT IS ONE OF EIGHT TECHNICAL APPENDICES DESCRIBING GEOLOGIC, HYDROGEOLOGIC AND GEOTECHNICAL CONSIDERATIONS OF THE CANDIDATE SITES. IT SUPPORTS THE COMPARATIVE EVALUATION STUDY WHICH IS ENTITLED "SITE SELECTION PROCESS; PHASE 4A, SELECTION OF PREFERRED SITE(S), GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS".

SEPTEMBER, 1985

PROJECT: 85-S18.3

Gartner Lee
Associates Limited



Gartner Lee Associates Limited

Consulting Engineering
Geologists
Biologists and
Hydrogeologists

Toronto-Buttonville Airport ▪ Markham, Ontario ▪ L3P 3J9 ▪ 416-477-8400
Telex-06-986278

September 12, 1985.

Dr. B.D. Mitchell,
Director of Corporate Planning
and Development,
Ontario Waste Management Corporation,
2 Bloor Street West,
11th Floor,
Toronto, Ontario,
M4W 3E2.

Attention: Mr. J.G. Micak,
Manager,
Environmental Projects

Dear Dr. Mitchell:

Re: Site Selection Process - Phase 4A
Technical Appendix PI-27E - Geologic, Hydrogeologic,
and Geotechnical Considerations

Enclosed are five copies of our final report on the Geologic, Hydrogeologic, and Geotechnical Considerations at Candidate Site PI-27E. Similar reports prepared for each of the other candidate sites will form the basis for site comparisons.

Thank you for allowing our company to be of service.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

Grant Anderson

E.G. Anderson, P.Eng.,
Project Director.

KJG:jcm
Enclosures.

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STUDY TEAM

This report was prepared under the overall direction of Grant Anderson, P.Eng., Project Director and Gunther Funk, Project Manager. Major contributing authors were:

Hydrogeology	Kenneth Goff
Geology	Andrew Cooper
Geotechnics	Douglas Jagger, P.Eng.
Field Co-ordination	Norbert Woerns

1.0 INTRODUCTION

1.1 BACKGROUND

The Ontario Waste Management Corporation's (OWMC) site selection process to locate facilities for treating hazardous wastes and disposing of the treated waste residues has been a phased process which began in 1981. Initial studies identified 261 hydrogeologic areas throughout southern Ontario which were grouped into six zones. Within the Golden Horseshoe, Zone 1 and 2 lands were considered most favourable for facility siting. Twenty candidate areas were identified within the Zone 1 and 2 lands in the Golden Horseshoe in 1983. A total of 152 sites were identified in these twenty candidate areas in 1984 and this number was subsequently reduced in stages to sixteen potential sites and finally to eight candidate sites through the application of various constraints, screening processes, and ranking systems based on multidisciplinary factors. A more complete discussion of the site selection process is provided in the comparative evaluation study (Gartner Lee Associates Limited 1985).

The present stage of study is the comparative assessment of the eight candidate sites. This Gartner Lee Associates Limited (GLAL) report documents and interprets available geologic, hydrogeologic, and geotechnical information for Site PI-27E and serves as the data source for input to the comparison study. The candidacy of this site is based on the potential development of a partially integrated treatment facility. The Phase 3B prelimiinary assessment of this site was based primarily on existing data (GLAL 1984b). Phase 4A

investigations described in this report add significantly to the geologic, hydrogeologic, and geotechnical data base.

1.2 OBJECTIVES AND SCOPE

The objective of this study is to provide data for Site PI-27E to accomodate comparisons with the other siting alternatives. This objective has been met through additional investigations. The existing data base has been upgraded where possible and five boreholes have been drilled on the site. Each of the boreholes has been continuously sampled to provide detailed geologic logs and soil samples. Boreholes were not instrumented and were grouted on completion.

1.3 LOCATION

Site PI-27E is located in the east-central portion of the Niagara Peninsula. It is shown together with the seven other candidate sites in Figure 1 and is presented in greater detail in the figures in the map pockets at the rear of the report.

The site under consideration on this Technical Appendix covers approximately 188 hectares (ha) and includes parts of Lots 1, 2, 3, and 4, Broken Front Concession (Welland River), City of Niagara Falls (formerly in the Township of Crowland), Regional Municipality of Niagara. The site is bounded on the north by Grassy Brook Road, on the south by Biggar Road (Regional Road 47), and on the east and west by Montrose Road (Regional Road 98) and Crowland Avenue respectively. It is roughly centred in a study area of about 2000 ha.

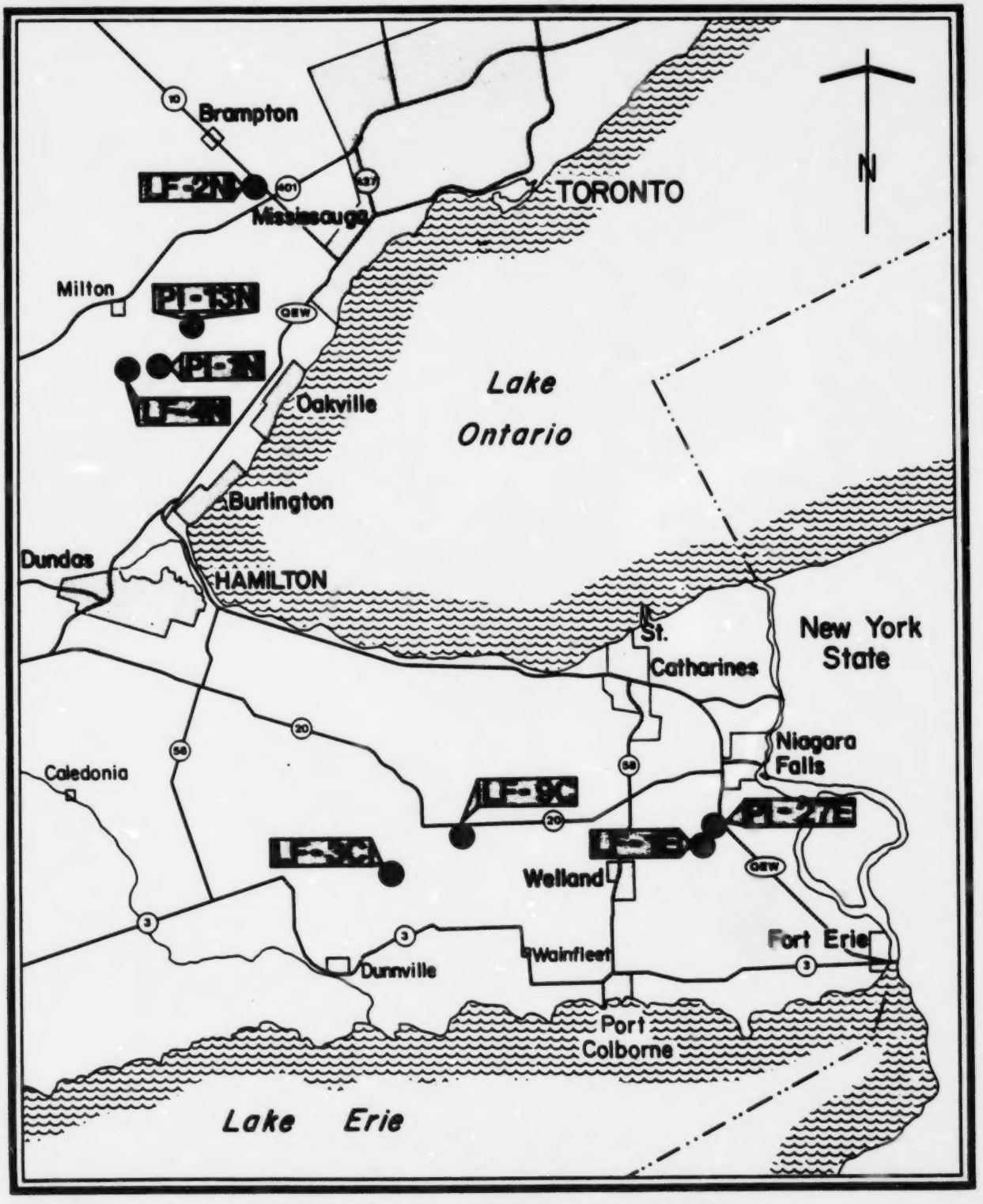


FIGURE 1 LOCATION OF CANDIDATE SITES

The site is located within the corporate limits of the City of Niagara Falls. It lies directly west of the Queen Elizabeth Highway (QEW) and is approximately 1 km northeast of Site LF-1E. It is adjacent to the Welland River at its northwestern corner and is roughly bisected by a hydro and railway corridor which crosses the site from southwest to northeast.

2.0 METHODOLOGY

The methodology employed in the collection, compilation, and interpretation of the information base presented in this technicial appendix report is described below and is illustrated in Figure 2.

2.1 DATA COLLECTION

The following sources of information were used:

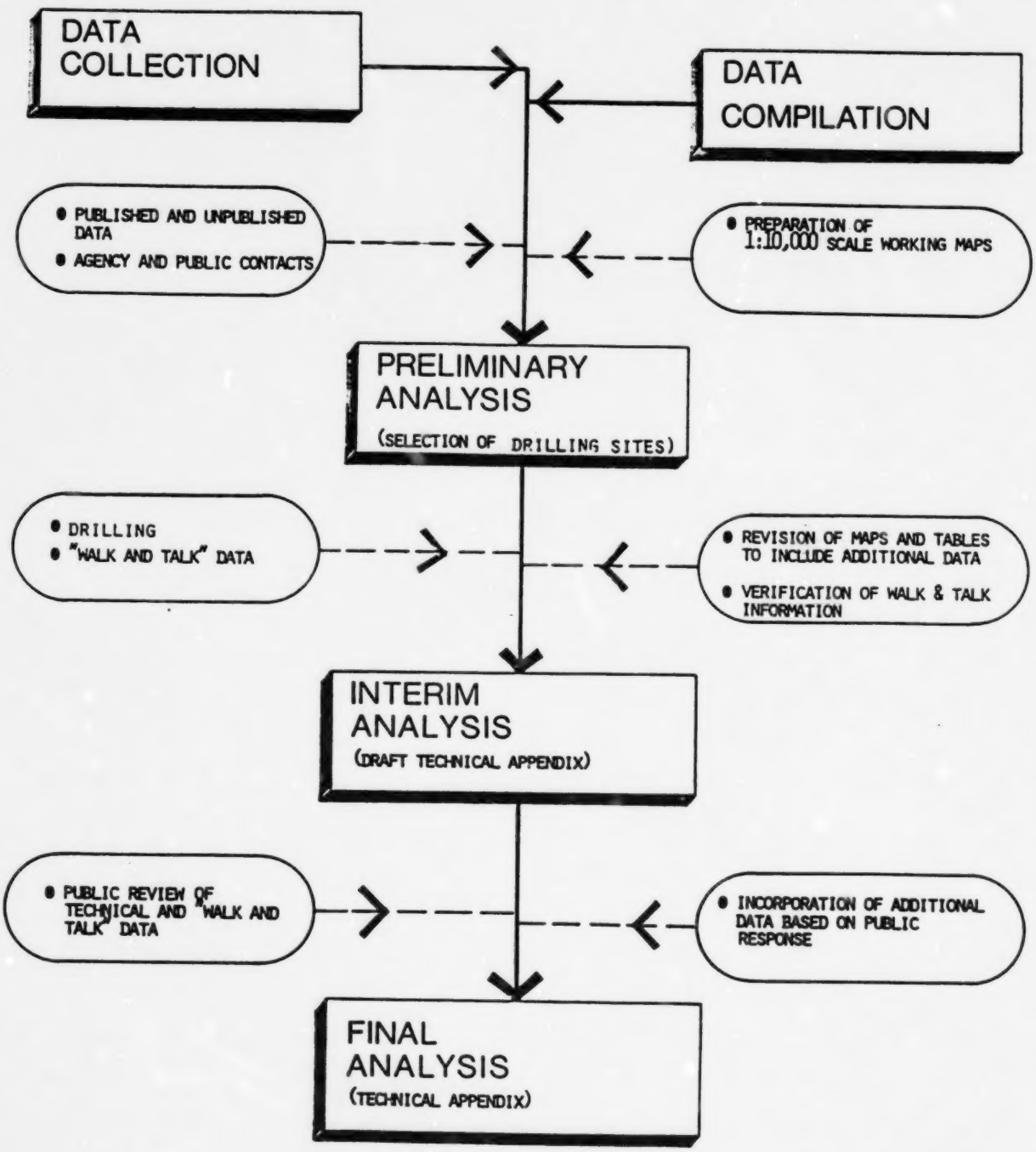
- water well and borehole records, published and unpublished reports, maps, and "open file" reports;
- interviews with government agency personnel and local residents; and
- onsite drilling and field survey results.

2.1.1 DATA BASE:

Numerous reports and maps which contain both regional and local information on the geology and hydrogeology of the candidate sites were assembled during the earlier phases of the site selection process. Reports specific to this site are referenced in the text and are listed in Section 7.0. Data summaries are provided in Section 8.0.

Figure 2

Methodology Flow Chart


DATA COLLECTION
DATA COMPILATION
• PUBLISHED AND UNPUBLISHED DATA
• AGENCY AND PUBLIC CONTACTS
• PREPARATION OF 1:10,000 SCALE WORKING MAPS
PRELIMINARY ANALYSIS
(SELECTION OF DRILLING SITES)
• DRILLING
• "WALK AND TALK" DATA
• REVISION OF MAPS AND TABLES TO INCLUDE ADDITIONAL DATA
• VERIFICATION OF WALK & TALK INFORMATION
INTERIM ANALYSIS
(DRAFT TECHNICAL APPENDIX)
• PUBLIC REVIEW OF TECHNICAL AND "WALK AND TALK" DATA
• INCORPORATION OF ADDITIONAL DATA BASED ON PUBLIC RESPONSE
FINAL ANALYSIS
(TECHNICAL APPENDIX)

Supplementary information was collected with the co-operation of government and other agencies. This information includes:

- copies of original water well records obtained from the Ministry of the Environment,
- copies of borehole records from the Ministry of Transportation and Communications and the City of Niagara Falls, and
- copies of borehole records from the St. Lawrence Seaway Authority.

These data are summarized in Section 8.0 of this report. Copies of the data are on file.

2.1.2 INTERVIEWS:

Additional information regarding site geology and water supply and use was obtained during interviews with government agency personnel and local residents. The results of interviews are presented in the summaries prepared for agency meetings (by GLAL) and on resident interview forms (prepared by Ecologistics Ltd.). Meetings were held with the local public interest groups made up of residents and other interested individuals who identified items of geologic and hydrogeologic interest. The summaries of meetings and the interview forms are on file. Local water use information summarized from the interview forms is tabulated in Section 8.3.

2.1.3 DRILLING AND FIELD SURVEY RESULTS:

Borehole locations were based on preliminary analyses of available data and input from the public. Five boreholes were completed on the site to investigate the expected character and

continuity of the geologic materials. Drilling and sampling procedures are presented in the document entitled "Phase 4A Drilling and Sampling Activities and Protocol" (GLAL 1984a) and the detailed methods employed during this study are summarized in Section 8.7.

The drilling program involved the collection of continuous samples from boreholes. These samples were photographed and described in the field, placed in suitable containers, and shipped to the Ontario Geological Survey in Toronto for storage. Split spoon samples were taken at 1.5 m intervals to obtain standard penetration resistance values and samples for moisture content determinations in order to carry out preliminary geotechnical assessments. Detailed borehole logs were prepared based on the field descriptions and on subsequent re-examination of the samples in storage. These logs are presented as part of the supporting information in Section 8.4.

2.2 DATA COMPILATION AND ANALYSIS

Data compilation and analysis has proceeded in a staged fashion which is depicted in Figure 2. In the initial work, information such as water well data was compiled in summary tables and illustrated on a series of working maps and cross sections at a scale of 1:10 000. Maps included plots of:

- data point locations (all sources);
- geology (Ontario Geological Survey reports, constraint mapping results from Phase 3B and Ministry of the Environment maps and reports);
- bedrock elevations (water well, oil and gas well, and borehole data);

- confining layer thickness (water well and borehole data);
- aquifer thickness (water well data);
- aquifer information (water well data); and
- anomalies such as granular zones (water well and borehole data).

These maps were used to establish the geographic distribution of existing data points and to confirm, at a more detailed scale, the preliminary interpretation of geologic and hydrogeologic conditions as presented in the Phase 3B documentation (GLAL 1984b). Tentative drilling locations were then identified based on these preliminary analyses.

Following the selection of tentative drilling locations, GLAL personnel met with interested parties to present the results of the preliminary analysis and to discuss the purpose and scope of the Phase 4A program. Additional information on local geologic and hydrogeologic conditions was collected during these meetings. (Water use information provided by the public is incorporated in the water use portion of this report). Landowners and tenants were contacted at this time to obtain permission to drill on their properties and drill site locations were modified based on local inputs.

A separate data collection program commonly referred to as the "Walk and Talk" survey was also undertaken. During this survey, individual residents were interviewed by personnel from Ecologistics Limited and the results were recorded in a questionnaire format. Among the multidisciplinary questions were several which were provided by Gartner Lee Associates Limited and which related specifically to water supply and use. The collection of ground water information and related water

use data was limited primarily to the site and to adjacent properties.

With the completion of the drilling and public survey programs, the working maps were revised to incorporate the additional information that was collected. This technical appendix presents an interpretation of geologic, hydrogeologic, and geotechnical conditions at PI-27E to date. Draft copies of data summaries were circulated to the local interest groups as a check on completeness and accuracy.

3.0 REGIONAL GEOLOGY AND HYDROGEOLOGY

The geology and hydrogeology of the Niagara Peninsula are summarized and discussed in reports prepared for the Ontario Waste Management Corporation (GLAL 1984b,c). This section is based on these reports and the reader is referred to them for more detail and for a complete list of references on which they are based.

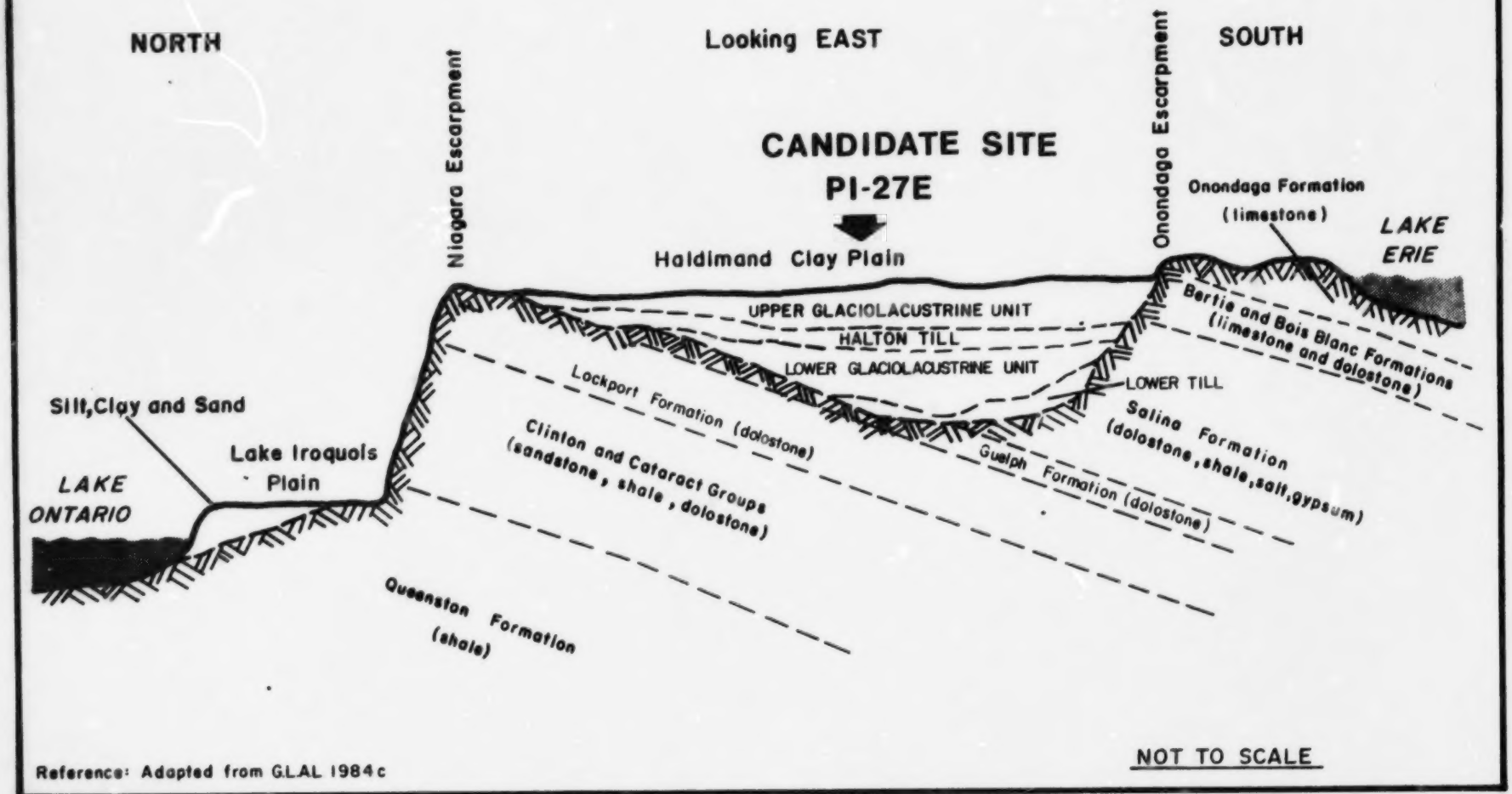
3.1 REGIONAL GEOLOGY

3.1.1 BEDROCK GEOLOGY AND OVERBURDEN THICKNESS

Bedrock in the Niagara Peninsula consists of a sequence of sedimentary formations which dip slightly to the south. This southerly dip exposes the various formations on the buried bedrock surface in east-west trending bands. Figure 3 shows the approximate location of Site PI-27E on a generalized cross-section of the Peninsula and names the

FIGURE 3

Cross-Section Sketch Through The Eastern Niagara Peninsula



Reference: Adapted from G.L.A.L. 1984c

Gartner Lee Associates Limited

major geologic units. The site is located over a bedrock depression of regional dimensions between the Niagara and Onondaga escarpments near the contact of the Guelph and Salina formations. Depths to bedrock in the vicinity of the site are in the 15 to 30 m range.

3.1.2 QUATERNARY GEOLOGIC HISTORY

Regional overburden units are indicated on Figure 3. From oldest to youngest they are (1) a lower till which directly overlies the bedrock, (2) a lower glaciolacustrine unit, (3) an upper till (Halton), and (4) an upper glaciolacustrine unit. The geologic sequence of events associated with these deposits began with a major ice advance which deposited the lower till over the Niagara Peninsula. This ice advance occurred about 23 000 years ago and the ice remained there until it withdrew northward approximately 14 000 years ago. Deposition of the lower glaciolacustrine unit occurred in a subsequent glacial lake. A brief readvance of the ice into the glacial lake resulted in the deposition of Halton Till about 13 000 to 12 000 years ago. As the Halton ice withdrew, a lake re-formed in front of it and the upper glaciolacustrine unit was deposited. Following drainage of this lake, the upper glaciolacustrine deposits have been subjected to weathering and erosion to produce the present landscape.

3.1.3 QUATERNARY GEOLOGY:

Generalized descriptions of each of the major overburden units are presented to provide a regional perspective on their characteristics and distribution. These are also used to place the discussion of the site geology into context.

A sandy silt to silty sand till occurs above the bedrock

at scattered locations throughout the Niagara Peninsula (Feenstra 1974, 1975, 1981, Barnett 1975) and it is generally acknowledged to be the Wentworth Till. This unit is also noted in the literature as the "lower till" and this term is used here. The lower till is inferred in about a third of the water well logs in the study area, where it is identified as 'clay and stones', 'clay and gravel' and 'hardpan'. About half the water well records report sand and gravel between the lower till and the bedrock. The regional distribution of basal granular deposits is described in previous reports (GLAL 1984b,c).

Owen (1969,1972) and Feenstra (1981) have described a lower glaciolacustrine deposit between the lower till and the Halton Till. They note a regional composition which includes clays, silts, and sands and indicate that this layered deposit is often only a few metres thick.

The Halton Till occurs between the upper and lower glaciolacustrine deposits over most of the Niagara Peninsula. The till is generally buried beneath upper glaciolacustrine deposits and is not usually exposed at surface. It may outcrop where the upper glaciolacustrine unit is eroded in valleys, where the Halton Till thickens in moraines, or where bedrock is exposed at the escarpments. The Halton Till does not outcrop on or in the immediate vicinity of Site PI-27E. The Niagara Falls Moraine has been mapped approximately 4 km north of the site and a partly buried moraine ('Walnut Hill') has been identified approximately 2 km south of the site (adjacent to Site LF-1E). Till composition reflects the silt and clay textures of the underlying glaciolacustrine deposits which are incorporated into it. Feenstra (1981) notes that the typically

clayey and silty Halton Till deposits are interspersed with sand and silty sand lenses on several moraines in the Niagara area. Portions of the Halton Till may be waterlain according to Feenstra (1981).

The upper glaciolacustrine unit consists of silts and clays which occur at surface over a large portion of the Niagara Peninsula and which constitute the Haldimand Clay Plain. Feenstra (1981) describes it as a "massive or stratified (varved in places) silty clay ... with generally more than 50 % clay and 5% sand". Feenstra (1975) also notes that this unit has been observed to be up to 16 m thick. Thin lenses and laminae of sand have been observed within the upper 2 m of the upper glaciolacustrine unit at several locations in the region. Glaciolacustrine deposits occur at surface over the site and in the general vicinity. The upper and lower glaciolacustrine units and the Halton Till are considered to comprise the 'clay' deposits which account for most of the materials noted in the water well record logs.

Alluvial deposits occur in association with flood plains of the streams and rivers in the region and are confined laterally and from below by the upper glaciolacustrine unit. They tend to be fine-textured reflecting available source materials and low to moderate stream gradients.

3.2 REGIONAL HYDROGEOLOGY:

The regional distribution of bedrock units is illustrated in Figure 3. The Salina and the Guelph formations are major regional aquifers and their contact occurs near to the site. The Guelph aquifer produces the better yields and the better

water quality in the area although the water may locally be mineralized. Water quality in the Salina aquifer is generally poor ('sulphurous') due to the presence of evaporites (primarily gypsum) in the carbonate sequence. Hydraulic conductivity in both aquifers is usually best-developed in the upper few metres of the bedrock as a result of fracturing and dissolution.

Sand and gravel deposits which directly overlie the bedrock are occasional sources of water to drilled wells, however it is not uncommon for drillers to develop wells in the bedrock after reporting granular deposits above the rock. Where granular deposits directly overlie the bedrock, they are likely in good hydraulic connection with it. The lower till does not appear to be a source of water.

The upper and lower glaciolacustrine units and the Halton and lower tills comprise a single hydrostratigraphic unit of regional extent which is referred to in this report as the confining layer. Downward gradients exist across this unit, however ground-water flow rates and quantities are very small. Hydraulic conductivities reported in similar deposits by Desaulniers et al. (1981) near Wainfleet average approximately $3x10^{-10}$ m/s and several values reported in glaciolacustrine deposits near Lewiston, New York are also in the 10^{-10} m/s range (Wehran Engineering P.C. 1983). No drilled wells are known to obtain water from the confining layer.

The surficial fractured portion of the confining layer extends to depths which range up to several metres and dug and bored wells occasionally obtain water supplies within this zone. Saturated fracture systems and granular laminations within the

lacustrine deposits are considered to be the source of water to such wells. In view of the fine-textured character of the deposits and the limited porosity of the fractures, yields to most shallow dug and bored wells are expected to be low and users likely rely on well-bore storage for periods of peak use. Alluvium may also provide water supplies to shallow dug and bored wells at some flood plain locations.

4.0 SITE GEOLOGY AND HYDROGEOLOGY

The following discussions of geology and hydrogeology at Site PI-27E take into account the regional data and add the new borehole information. In addition, data from formal and informal field interviews are integrated into this analysis. Figure 4 (in map pocket) provides locations of the cross-sections and the field data presented in this report.

The GLAL borehole program is used primarily to assess the predictability and uniformity of subsurface conditions. Hydrogeologic discussions are based on the borehole geology and on such other sources of information as water well and borehole records and water use data provided by local residents. Table 1 compares local geologic and hydrostratigraphic units which are defined for the site and the vicinity. This table provides the framework for the discussions that follow, from the bedrock to the surface.

4.1 SITE GEOLOGY

Five continuously sampled boreholes were drilled to investigate the subsurface geology; three were cored into dolostone bedrock, one terminated in the lower till, and one terminated on a boulder in the lower glaciolacustrine unit. Gartner Lee Associates Limited borehole locations are shown in Figure 4 (in map pocket) along with water wells, oil and gas wells, and other boreholes (Ministry of Transportation and Communications, City of Niagara Falls, and St. Lawrence Seaway Authority). Logs of the boreholes and summaries of other subsurface data are included in Section 8.0. Geologic cross-sections through the study area are presented in Figures 5 and 6 (in map pocket). Cross-section geologic descriptions are simplified for presentation. The geologic names in the borehole logs (eg. Halton Till, lower glaciolacustrine unit) are used to relate local geology to the established regional geologic framework and are based on published descriptions.

4.1.1 TERRAIN

Site PI-27E is located on a portion of the Haldimand Clay Plain (Chapman and Putnam 1966). The site is generally flat to gently rolling except where it is dissected by stream erosion. Elevations range from about 180 metres above sea level (m a.s.l.) along the southern boundary to about 174 m in the northeast corner adjacent to Grassy Brook. The site drains to the Welland River.

TABLE 1: SUMMARY OF LOCAL GEOLOGIC AND HYDROSTRATIGRAPHIC UNITS

GEOLOGIC UNIT		HYDROSTRATIGRAPHIC UNIT
ALLUVIUM		ALLUVIUM
UPPER GLACIO-LACUSTRINE SAND	CONFINING	FRACTURED ZONE (UPPER GLACIOLACUSTRINE)
HALTON TILL	SAND	UNFRACTURED ZONE (UPPER GLACIOLACUSTRINE, HALTON TILL, LOWER GLACIOLACUSTRINE)
LOWER GLACIO-LACUSTRINE SAND	LAYER	
LOWER TILL		LOWER TILL
BASAL GRANULAR BEDROCK (GUELPH DOLOSTONE)	BASAL GRANULAR AND BEDROCK AQUIFERS	

Note: Alluvium occurs along the Welland River and probably along portions of the two water courses which transverse the site.

4.1.2 BEDROCK GEOLOGY AND DRIFT THICKNESS:

GLAL boreholes which were cored into bedrock encountered grey dolostone with occasional vugs and thin shaly interbeds. These descriptions are similar to those provided by Telford et al. (1976) and are considered to indicate the Guelph Formation. According to Telford et al. (1976), the contact with the Salina Formation lies slightly north of the site, however GLAL bore-

hole logs suggest that the site is underlain by Guelph dolostone and it is probable that the Guelph-Salina contact occurs farther to the south. A shallow east-west trending bedrock depression occurs beneath the site and appears to deepen to the west. Elevations on the bedrock surface range from about 148 m a.s.l. to about 160 m on the site.

Overburden thicknesses in the GLAL boreholes and in the three onsite water wells (for which records are available) range from about 17 m to 30 m.

4.1.3 BASAL GRANULAR UNIT:

No basal granular deposits were encountered in the GLAL boreholes, however several water well logs in the study area and two of three wells on the site report the occurrence of sand and gravel between the bedrock and the lower till. It is considered that the basal granular unit is discontinuous beneath the site.

4.1.4 LOWER TILL:

A sandy silt to silt till was encountered (inferred in Borehole GL4), between the bedrock and the lower glaciolacustrine unit in the GLAL boreholes (Figures 5 and 6). This lower till rests directly on bedrock and ranges in thickness from 0.7 to 3.3 m. It is typically brown, very dense, saturated, and shows minor variability in texture between boreholes. Water well logs generally report 'stony clay', 'clay and gravel', or 'hardpan' between the 'clay' and bedrock (except where basal granular deposits are reported) and such deposits are inferred to be the lower till.

4.1.5 LOWER GLACIOLACUSTRINE UNIT:

This unit ranges in thickness from 0.2 to 15.5 m across the site. It consists generally of laminated silty clay and clayey silt with occasional pebbles in Boreholes GL1, GL2, and GL5 and of silty fine to medium sand in Boreholes GL3 and GL4 (Figure 4). The lower glaciolacustrine deposit is thickest in Boreholes GL3 and GL4 as these locations occur within the bedrock depression noted earlier. The presence of sand within the lower glaciolacustrine unit is discussed in Feenstra (1981). He also notes a general association of sand occurrences with bedrock depressions.

4.1.6 HALTON TILL:

The Halton Till was encountered in all the GLAL boreholes and ranges in texture from silty clay to clayey silt to silt (except in Borehole GL5, where it is a sandy to clayey silt). A silty fine sand inclusion approximately 20 cm thick is reported in Borehole GL2, however no other granular zones were noted in the Halton Till and this inclusion is considered to be a local feature. The Halton Till differs from the adjacent glaciolacustrine units by being more massive and indistinctly laminated (Section 8.4). The Halton Till varies between 0.8 and 7.6 m in thickness in GLAL boreholes (Section 8.4). The laminations and gradational contacts with the adjacent glaciolacustrine units suggest a waterlain origin and is consistent with the geologic history of the region proposed by Feenstra (1981).

4.1.7 UPPER GLACIOLACUSTRINE UNIT

This unit is typically a brown to dark grey silty clay to clayey silt with occasional pebbles less than a centimetre in size. Exceptions occur in Borehole GL3, in the north central

portion of the site, where the lower half (approximately) of the upper glaciolacustrine unit consists of silty fine sand to sandy silt and in Borehole GL1 where fine sand laminae occur at a depth of 6.5 m. The deposit is usually laminated but may contain massive zones. A subtle colour change occurs from brown to grey brown or grey at depths of 3 to 4 m. The upper 1 to 2 m is more intensely fractured and rarely shows visible laminations. Fracture frequency decreases rapidly with depth and fractures are infrequent below about 5 m. The deepest evidence of fracturing was noted in Borehole GL5 at a depth of 6.4 m (Section 8.4). Grey carbonate infilling (with a clay-like texture) was observed in many fractures. Occasional silt laminae (1 to 2 mm thick) occur throughout the unit, and silt is the dominant material in the 6 to 12 m interval in Borehole GL1. The upper glaciolacustrine unit ranges in thickness from 8.6 m in Borehole GL4 to 18.0 m in Borehole GL2.

4.1.8 ALLUVIUM

Alluvial deposits underlie the flood plain of the Welland River which occurs adjacent to the northeast corner of the site, however the Welland River flood plain is developed on the north side of the river at this location. There is no known alluvium of any significance on the site, although thin, discontinuous deposits may occur along the two watercourses which traverse the site, especially in their downstream portions near the eastern site boundary.

4.1.9 DISCUSSION

Geologic conditions at Site PI-27E are locally variable. Bedrock depths range from about 17 m in the south to more than 30 m in the north and each of the geologic units demonstrates stratigraphic and textural variability. Bedrock occurs at

shallower depths in the south and southeast portions of the site and at greater depths in the north and northwest portions of the site. It appears that the normally fine-textured geologic units thicken and become more coarse textured where the bedrock is deeper. In general, the geologic units which comprise the overburden are more uniform and predictable in the south and southeast and less uniform and predictable in the north and northwest.

4.2 SITE HYDROGEOLOGY

The Phase 4A field work incorporates first-hand geologic descriptions and interpretations with the existing data base (primarily water well record and borehole information). Hydrogeologic analyses utilize the geology, the water well and borehole records, information obtained from the public, and information supplied by researchers in similar hydrogeologic settings together with the experience of GLAL staff. Descriptions of the hydrostratigraphic units, flow systems, ground water use, and potential contaminant pathways are presented in the following sections.

4.2.1 HYDROSTRATIGRAPHY:

Three major hydrostratigraphic units are identified at Site PI-27E. These are: (1) the fractured bedrock and associated basal granular aquifers, (2) sand layers within the glaciolacustrine units and (3) a confining layer which extends from the surface to the depth of the first significant granular deposit or to bedrock. The confining layer contains up to three hydrostratigraphic subunits which may include (i) the lower till, (ii) the lower glaciolacustrine unit, the Halton Till, and the unfractured portion of the upper glaciolacustrine unit,

and (iii) the surficial fractured portion of the upper glaciolacustrine unit. Confining layer thicknesses at available data points are presented in Figure 7 (in map pocket).

4.2.1.1 Bedrock and basal granular aquifers

The bedrock is the most important source of water to drilled wells in the study area. GLAL boreholes at three locations encountered dolostone which showed numerous horizontal bedding planes and occasional small vugs. The upper weathered portion of the bedrock is sufficiently permeable to sustain test pumping rates which average about 0.7 litres per second (L/s) based on water well records for the study area.

The upper few metres of the bedrock is fractured and is considered to constitute a permeable zone which is an avenue for lateral ground water flow. The consistency with which bedrock wells have encountered adequate water supplies in this zone suggests well developed horizontal fracturing, however the variability in pumping rates and drawdowns indicates that the fracturing is irregular. The average hydraulic conductivity of this zone is estimated to be 3×10^{-5} m/s based on local water well record data and calculations described by Walton (1962) and Ogden (1965). The porosity of the upper bedrock is considered to be approximately 0.01 and a lateral gradient of 0.002 is estimated from the elevations of reported static water levels in study area water wells (Section 8.1).

Most of the well records in the study area report basal granular deposits above the bedrock and water supplies have been developed in these deposits at three locations. Two of four test wells drilled immediately north of the site were screened opposite a basal sand and gravel (one was screened opposite a

sand deposit above the lower till). Granular deposits between the lower till and the bedrock are considered to be discontinuous, however where present, they are expected to have good hydraulic connection with the bedrock.

4.2.1.2 Granular within the glaciolacustrine deposits
The upper and lower glaciolacustrine units are part of the confining layer in Boreholes GL1, GL2, and GL5 where they are typically clayey and silty in texture. However, in Boreholes GL3 and GL4, the lower glaciolacustrine unit consists of silty fine sand and fine sand and in Borehole GL3 the lower half of the upper glaciolacustrine unit is also sandy. The granular texture of these units in Boreholes GL3 and GL4 makes them unsuitable for inclusion in the confining layer.

4.2.1.3 Confining layer: The confining layer extends from surface to the first significant granular zone which has aquifer potential or which is considered to offer potential for offsite ground water movement. The confining layer is characterized by fine-textured materials with low hydraulic conductivities and may contain up to three hydrostratigraphic subunits depending on local conditions. The confining layer extends to bedrock in Boreholes GL1, GL2, and GL5; terminates in fine sand midway through the upper glaciolacustrine unit in Borehole GL3; and extends to the base of the Halton Till in Borehole GL4.

Each of the confining layer subunits is described in the following paragraphs and Table 2 summarizes their thicknesses and selected hydrogeologic properties.

TABLE 2: SUMMARY OF CONFINING LAYER CHARACTERISTICS

BOREHOLE PARAMETER	THICKNESS OF CONFINING LAYER SUBUNITS			THICKNESS OF CONFINING LAYER
	LOWER TILL (m)	UNFRACTURED GLACIOLACUSTRINE UNITS: HALTON TILL (m)	SURFICIAL FRACTURED ZONE (m)	(m)
GL1	1.3	19.8	5.0	26.1
GL2	3.3	9.3	5.0	17.6
GL3	N/A	1.3	5.0	6.3
GL4	N/A	11.2	5.0	16.2
GL5	0.7	11.7	5.0	17.4
Average Hydraulic Conductivity m/s	1.0×10^{-8}	3.0×10^{-10}	1.0×10^{-8}	
Average Porosity	0.3	0.5	0.0001	

Notes: N/A - not applicable
- Unfractured porosity values are estimates of total intergranular porosity
- The fractured porosity value is the effective fracture porosity reported by Desaulniers (1982)
- Porosity values in the unfractured materials reflect intergranular porosity. Additional fracture porosity is present in the fractured zone. These fractures are accompanied by increased hydraulic conductivities with the result that ground water can potentially move more rapidly along fractures.

The lower till is part of the confining layer in Boreholes GL1, GL2, and GL5. It varies in texture from sandy silt to silt and ranges in thickness from 0.7 to 3.3 m at these locations. In Ministry of the Environment well records the lower till is described as 'stony clay', 'clay and gravel' and 'hardpan'. The average hydraulic conductivity of the lower till is considered to be less than that of the overlying glaciolacustrine and Halton Till units because of its silt and sandy silt textures. A value of $1x10^{-8}$ m/s (which is two orders of magnitude greater than the glaciolacustrine and Halton Till units) is applied to the lower till to reflect these textural differences. This average value is within the range of hydraulic conductivities for silt and for glacial till given by Freeze and Cherry (1979). The average porosity of the lower till is estimated to be 0.3 which is lower than the porosity of the more clayey overlying glaciolacustrine/Halton Till units.

Silty clays and clayey silts of the lower glaciolacustrine unit, the Halton Till, and the unfractured portion of the upper glaciolacustrine unit comprise the least permeable subunit of the confining layer. Hydraulic conductivities for this portion of the confining layer are considered to be similar to values reported by Desaulniers et al. (1981) in fine-textured deposits near Wainfleet. These values range from $1.1x10^{-10}$ to $8.2x10^{-10}$ m/s for laboratory tests and from $1.3x10^{-10}$ to $7.9x10^{-10}$ m/s for in situ tests. Porosities ranged from 0.34 to 0.60 at Wainfleet and the approximate average of this range (0.5) is applied to this portion of the confining layer at Site PI-27E. Laboratory and field testing of similar fine-textured glaciolacustrine deposits near Lewiston, New York yielded a range of hydraulic conductivities from $1.4x10^{-10}$ to $8.7x10^{-10}$ m/s over

depths from 4.7 to 10.0 m (Wehran Engineering, P.C. 1983). None of the 41 water wells (including 4 test holes) for which Ministry of Environment records are available in the study area terminates in the confining layer.

The upper 1 to 2 m (approximately) of the confining layer is most severely fractured, however fracture frequency declines rapidly with depth as fractures become more tightly closed and fewer. Based on borehole logs (Section 8.4) it is estimated that fracturing is generally limited to depths of 5 m or less and while occasional fractures are noted at greater depths they are rare. The deepest fracture noted on the site occurs at 6.4 m in Borehole GL5. Freeze and Cherry (1979) note that deposits of clayey or silty till and glaciolacustrine deposits in southern Ontario contain networks of hairline fractures which are essentially vertical and which are responsible for hydraulic conductivities one to three orders of magnitude greater than in unfractured materials. Based on this observation, the fractured zone is assigned a hydraulic conductivity of 1×10^{-8} m/s which is approximately two orders of magnitude greater than the underlying unfractured deposits. The surficial fractured zone is included within the confining layer because it is part of the upper glaciolacustrine unit and is clayey and silty in texture. While the higher hydraulic conductivity is applied over a 5 m interval, fracturing is significant only in the upper 1 to 2 m, as deeper fractures are more tightly closed and fewer in number. Desaulniers (1982) reports an effective fracture porosity of 0.0001 in glacio-lacustrine deposits in Lambton County. These deposits are considered similar to materials at this site and this porosity value is considered to be applicable here.

No dug wells are reported on the site, however a bricked well is located immediately beyond the northeast corner of the site adjacent to a watercourse. No other dug or bored wells were reported within the study area. Local water supply is discussed in Section 4.2.3.

4.2.1.4 Discussion

Hydrogeologic conditions at Site PI-27E are locally variable. The confining layer is thickest in southern portions of the site where it extends to the bedrock. At northerly locations, granular textures predominate in the glaciolacustrine units effectively reducing the confining layer thickness. Granular textures appear to be related to a bedrock depression which underlies the northern portion of the site. Predictability and uniformity with respect to subsurface materials are considered to be relatively good in the south and fair to poor in the north.

4.2.2 GROUND WATER FLOW REGIME

Infiltration is the source of ground water and differences in hydraulic head provide the driving force for ground water flow systems. At the site, shallow lateral flow is considered to exist in the saturated portion of the fractured zone. Within the confining layer, ground water flow is vertically downward and within granular deposits and the shallow bedrock flow is expected to be lateral. Ground water flow tends to be mainly vertical in fine-textured materials and lateral in granular deposits which have lateral continuity and lateral gradients. Downward gradients are indicated by a water table which is close to the surface and by water levels in the underlying aquifer which are several metres below ground. The ground water flow system is discussed below and estimates of flow rates are

provided for comparative purposes. Parameters used in these estimates are summarized in Table 3 for convenient reference.

The water table occurs in the fractured zone and its shape is a reflection of topography. Fracturing and ground water flow diminish rapidly to the base of the fractured zone which extends to a depth of about 5 m on the site. The shallow flow system is most active in the upper 1 to 2 m where fracturing is most common and where fracture permeability is best developed. Movement in the shallow flow system is essentially lateral and rates and directions of flow are dependent on elevation differences in the water table.

The average hydraulic conductivity in the fractured zone is estimated to be 1×10^{-8} m/s, the effective fracture porosity is estimated to be 0.0001 based on Desaulniers' work in Lambton County (1982) and the onsite water-table gradient is inferred to be approximately 0.003. Based on these values, the lateral flow rate is approximately 3×10^{-7} m/s or 10 m per year. The quantity of flow in the shallow system is greatest when the water table is closest to ground level and the saturated zone is thickest. Flows are greater in the fractured zone than in the underlying unfractured materials. Estimated rates of fracture flow are usually large relative to rates of flow in granular porous media because of large differences in porosity. Fracture flow rates are unrealistically large if they are interpreted as 'straight-line' pathways because fracture systems may be complex and interconnections may be indirect or poorly developed.

Ground water potentials in the unfractured portion of the confining layer are downward, however flow rates and amounts of

flow are expected to be very small. The downward gradient is estimated to be 0.25 based on a water table assumed to be at ground surface and water levels in the bedrock aquifer which are averaged from wells on and adjacent to the site. Hydraulic gradients measured by Desaulniers et al. (1981) near Wainfleet were vertically downward and ranged between 0.02 and 0.17 over depths to approximately 30 m in fine-textured deposits. Estimated downward flow rates through the three hydrostratigraphic subunits which comprise the confining layer are summarized in Table 3. These rates are calculated using a method described by Freeze and Cherry (1979) which is reproduced in Section 8.5 along with a sample calculation. Since flow rates in the fractured zone are three to four orders of magnitude greater than in deeper portions of the confining layer (Table 3), it is apparent that the unfractured portion of the confining layer controls ground water flow. Desaulniers et al. (1981) concluded that pore waters in deeper fine-textured deposits at southwestern Ontario locations are approximately 8700 to 9800 years old.

A more accurate assessment of ground water flow rates through the confining layer using advection and diffusion calculations is contained in Appendix A of the report entitled "Site Selection Process, Phase 4A; Selection of Preferred Site(s), Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

Ground water movement in the bedrock beneath the study area occurs primarily within the upper fractured zone where fractures are best developed and where they have been enlarged by solution. Most bedrock wells obtain water in the upper 2 to 3 m and the zone of increased permeability is considered to be

about 5 m thick. The average hydraulic conductivity of this zone is about $3x10^{-5}$ m/s and the average porosity is considered to be approximately 0.01. The direction of ground water flow within the study area appears to be toward a bedrock depression which roughly traverses the site from east to west. This depression deepens to the west and it is likely that ground water flow is also westward, however there is insufficient water level information to clearly infer a direction of flow. Estimated flow rates through the upper bedrock could be as rapid as $1x10^{-4}$ m/s or 200 m/year based on the above values and a gradient of 0.002. As indicated previously, fracture flow rates may be unrealistically large if they are interpreted over 'straight-line' distances since fracture connections are usually complex and interconnections may be indirect or poorly developed.

4.2.3 GROUND WATER USE:

Water use information is based on water well record data and on information collected from residents and landowners on the site and on adjacent properties. A report issued by the Ontario Water Resources Commission (1964) describes water resources of the County of Welland and of Crowland Township.

4.2.3.1 Availability

Water supplies for domestic, stock, and general agricultural purposes are obtained primarily from drilled wells and cisterns and occasionally from ponds. Bottled water for drinking is reportedly used at one residence near the site and cisterns are supplied with trucked water at two other locations (one onsite). Water use information is summarized according to source in Figure 8 (in map pocket) and is supported by site interview data ('Walk and Talk') summaries in Table 6 (Section 8.3).

TABLE 3: ESTIMATED VERTICAL FLOW RATES IN THE CONFINING LAYER

GLAL BOREHOLES	CONFINING LAYER FLOW RATES		
	FRACTURED ZONE (m/s)	UNFRACTURED GLACIO-LACUSTRINE UNITS & HALTON TILL (m/s)	LOWER TILL (m/s)
GL1	$1x10^{-6}$	$2x10^{-10}$	$3x10^{-10}$
GL2	$1x10^{-6}$	$3x10^{-10}$	$5x10^{-10}$
GL3	$3x10^{-6}$	$7x10^{-10}$	N/A
GL4	$1x10^{-6}$	$2x10^{-10}$	N/A
GL5	$1x10^{-6}$	$2x10^{-10}$	$4x10^{-10}$

Notes: - Average hydraulic conductivity and porosity estimates are provided along with thicknesses for the confining layer subunits in Table 2.

- Multiply by $3.15x10^{7}$ for flow rates in metres per year.

N/A - Not applicable

Based on water well records and field information surveys, the bedrock and sand and gravel deposits on the bedrock surface are sources of water supply to drilled wells in the study area. Yields from the bedrock and from the sand and gravel do not appear to differ substantially. Test pumping rates during well development are usually in the range of 0.3 to 1.5 litres per second (L/s) and drawdowns in about three quarters of the cases are less than 10 m. Drilling contractors most frequently recommend pumping rates in the range of 0.3 to 0.75 L/s with pump settings between 10 and 20 m below ground level. Adequate supplies are usually obtained from the bedrock within the upper 2 m, although penetration depths up to 13 m are reported. The locations of wells which obtain water from basal granular deposits follow no apparent pattern and in several cases the driller has reported sand and gravel but has cased through it to obtain supplies from the bedrock.

Six additional wells were reported during field information surveys; two drilled wells are located on the site and three drilled wells and one dug well are located on adjacent properties. The drilled wells are similar in depth to those reported in the water well summary (Section 8.1) and are used for domestic, stock, and general agricultural purposes. The dug well is located adjacent to the north east corner of the site near the QEW. It is only 1.8 m deep and is located near Grassy Brook which exits the site at this location.

Rainwater cisterns are a common source of additional water supply in the study area. Most cisterns 'dry up' periodically during periods of low rainfall and several are maintained with trucked water. Dugouts and off-stream ponds are occasionally used for stock and agricultural purposes. Many dugouts likely

penetrate the water table although some may rely on surface runoff.

4.2.3.2 Quality

Ground water quality from the bedrock and from sand and gravel deposits on or near the bedrock contact (as reported in the water well records) is 'sulphurous' in about one-third of the wells in the study area and 'fresh' in the remainder. The 'sulphurous' ground water occurrences have no apparent pattern over the study area. One well which terminates in the basal sand and gravel is also 'sulphurous' and this is considered to indicate a good hydraulic connection between the basal sand and gravel and the bedrock. It is reasoned that 'sulphurous' water is common in the study area because of the proximity of the Salina aquifer. Ground water from the Guelph aquifer is usually reported as being 'fresh', 'hard', or 'mineralized'. One well (#3, Table 6) has been abandoned for reasons of poor water quality and other drilled wells are used for limited purposes because of marginal water quality).

4.2.4 POTENTIAL CONTAMINANT PATHWAYS

In general, there are two pathways by which contaminants could potentially leave this site; these are (1) natural pathways along ground water flow systems and (2) man-made pathways which follow such structures as abandoned and unplugged wells and tile drains. The natural pathways tend to retard ground water movement as a result of low hydraulic conductivity of the confining layer. Natural pathways have been discussed in Site Hydrogeology (4.2.1) and Ground Water Flow Regime (4.2.2).

Efforts have been made to identify and locate man-made structures such as water wells, gas wells, tile drainage

systems and excavations which may be located on the site. These structures could act as conduits or pathways along which contaminants could potentially leave the site. For example, improperly sealed and abandoned deep wells which penetrate the confining layer could provide access to the underlying aquifer. Shallow structures such as granular trench backfill and drainage tiles could provide direct access to surface water and shallow ground water.

A total of five water wells are known on the site; two were identified through field interviews and three were previously known from Ministry of the Environment records. Four are in active use and one is unused (by reason of poor quality). Well locations are shown in Figure 8 and all five wells are believed to penetrate the confining layer. Gas wells are common in the area, however Ministry of Natural Resources records indicate no onsite wells. Present information indicates that none of the site is tile drained.

Excavations are believed to be limited to the immediate vicinity of buildings on the site and no extensive corridors of permeable backfill materials were identified from the interview sheets.

5.0 GEOTECHNICAL CONSIDERATIONS

This section provides a preliminary soils engineering assessment of Site PI-27E. The geologic setting is described in detail in Section 4.0 of this report.

The geologic data base is supplemented by standard penetration and moisture content tests taken at 1.5 m intervals in the GLAL boreholes. The standard penetration (N) values have been used as a guide in estimating the relative density and consistency undrained shear strengths of the various materials. Undrained shear strengths noted here are estimated through correlations with shear-strength blow-count relationships obtained from other geotechnical studies in similar materials in the Niagara Peninsula. Moisture content determinations and N values are presented together with the borehole logs in Section 8.4. The geotechnical conditions at this site as related to the geological setting are described below.

A desiccated crust between 1 and 5 m thick is present under most of the site. It is comprised of silty clay and clayey silt which have a very stiff to hard consistency based on N values in the range of 19 to 37 (blows per 0.3 m). Corresponding undrained shear strengths vary from approximately 100 to greater than 200 kPa (kilopascals). The moisture content of these desiccated soils was in the 21 to 26% range.

The clayey textured materials below the desiccated crust are relatively uniform and predictable. These deposits have a firm to stiff consistency with N values up to 26 and undrained shear strengths approaching 150 kPa. In situ moisture contents were typically in the 20 to 30% range with occasional values to 42%.

In the northwestern portion of the site (as represented by Boreholes GL3 and GL4), sandy silt, silty fine sand, and medium sand comprise the lower portion of the upper glaciolacustrine

deposit and the lower glaciolacustrine deposit. These deposits are generally dense to very dense with N values typically in the range of 33 to 100. There are several localized zones where the sand is loose to compact (N's of 7 to 20). The in situ moisture contents within the sand range between 6 and 36%. (Higher values are associated with the silty and clayey phases within the sand).

The lower till which overlies the bedrock is typically very dense with N values greater than 50. The in situ moisture contents were generally less than 10%.

Preliminary assessments based on data from the GLAL boreholes indicate that geotechnical conditions at Site PI-27E will influence development from a soils engineering point of view. However it is considered that subsurface aspects can be handled with proper design and standard techniques.

Over most of the site there is a desiccated crust in which the clays and silts are generally very stiff to hard in consistency. This zone will provide adequate bearing pressure for light-weight structures with standard strip footings provided that most of the stresses are dissipated within the crust. The exception is in the area represented by Borehole GL2 where the desiccated crust is only about 1 m thick. Any settlement of light weight structures founded in the desiccated crust should be within tolerable limits.

Heavy structures will require a more detailed foundation design. Where loads are transferred into the clayey subsoils below the desiccated crust, stability and settlement may be a problem. This also applies to light-weight structures where

stresses extend beyond the desiccated crust. The lower till and bedrock are available for load transfer. As well, in Boreholes GL3 and GL4 in the northwest section of the site, dense to very dense sand beds may be available for load transfer. These aspects will require further investigation.

As a general guide, in the southeast half of the site, temporary excavations approximately 5 m below ground surface will present no problems if undertaken at 2:1 side slopes. There may be local areas (as represented by Borehole GL5) wnere excavations to 8 m may be feasible. In the northwest part of the site where sand occurs within 6 m of the surface, excavations would be limited to about 4 m without ground water control. Otherwise temporary excavations could be taken to 5 m below ground surface at 2:1 side slopes.

The clayey subsoils on the site are workable. However, due to their 'wet' and 'sticky' nature, they will be a nuisance from a materials handling and trafficability perspective. The nuisance aspect will be aggravated during wet weather.

6.0 SUMMARY

Site PI-27E is located on the Haldimand Clay Plain within the corporate limits of the City of Niagara Falls. The site is located near the Salina-Guelph bedrock contact and is underlain by Guelph dolostones. A bedrock depression occurs beneath the northern portion of the site. The overburden consists of a discontinuous basal granular deposit, a lower till, a lower glaciolacustrine unit, the Halton Till, and an upper glacio-

lacustrine unit. The glaciolacustrine units and the Halton Till tend to be uniformly clayey and silty textured in the south and southeast. In the north and northwest, portions of these units consist of sand and their geologic predictability and uniformity is decreased.

The three major hydrogeologic units in the study area are (1) the bedrock and basal granular aquifer, (2) granular zones within the glaciolacustrine units, and (3) the confining layer. The Guelph bedrock aquifer is a regional source of water supply and is the major source of domestic and farm supplies in the study area. Discontinuous basal sand and gravel deposits overlying the bedrock are occasionally utilized as sources of supply. Water quality from these sources ranges from 'fresh' to 'sulphurous'.

The confining layer comprises up to three subunits which include (i) the lower till, (ii) the lower glaciolacustrine unit, the Halton Till, and the unfractured portion of the upper glaciolacustrine unit, and (iii) tne surficial fractured portion of the upper glaciolacustrine unit. The confining layer ranges in thickness from about 6 m in the northwest portion of the site to about 26 m in the central part of the site. Vertical ground water flow in the confining layer is estimated to average about 0.01 m/year. The surficial fractured zone of the confining layer is about 5 m thick. Ground water movement in the saturated portion of this zone is essentially lateral in response to water table gradients and the rate of flow is estimated to be about 10 m per year.

Potential contaminant pathways off the site include natural flow systems and man-made conduits. Natural flow systems are

generally sluggish with the result that they would tend to contain and retard contaminant movement. Man-made conduits to the underlying aquifer on the site appear to be limited to water wells.

Preliminary geotechnical indications are that the desiccated crust can provide adequate bearing for light-weight structures using standard strip footings in most situations. Loads from heavy structures would be transferred to greater depths and would require further geotechnical testing for proper foundation design. In parts of the site, relatively shallow sands and silts may be considered for load transfer along with the lower till and the bedrock. Temporary excavations for construction may extend to depths of about 5 m (2:1 side slopes) at most locations on site, however local material strengths and textures should be considered at specific locations.

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8.0 SUPPORTING INFORMATION

8.1 SUMMARY OF WATER WELL DATA (TABLE 4)

8.2 SUMMARY OF OIL AND GAS WELL DATA (TABLE 5)

8.3 SUMMARY OF SITE INTERVIEW (WALK AND TALK) DATA, (TABLE 6)

8.4 BOREHOLE LOGS

8.5 SUPPORTING CALCULATIONS AND METHODS

8.6 GLOSSARY OF SELECTED TERMS

8.7 DETAILED FIELD METHODS

8.1 SUMMARY OF WATER WELL DATA

Water well locations are shown in Figure 4 (in map pocket).

Copies of original Water Well Records obtained from the Ministry of the Environment (MOE) were used for the following data summary and are on file.

Measurements, dimensions, and quantities on the Water Well Records are in Imperial units but are presented in metric units in the following summary.

Water well locations were plotted on 1:10 000 scale maps for this project and elevations were re-estimated, based on the more accurate contours on these maps. Well elevations are above sea level (ASL) and are estimated to the nearest metre.

Well records are arranged in numerical order.

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-22E

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
612	FORD MOTOR CO.: B.F. CON., LOT 1, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	176	JUN 1960	5.1	16.7	FRESH	17.4	2.4	3	0.6	TEST HOLE	0.0	0.3	TOPSOIL
												0.3	4.6	RED CLAY; STREAKS OF GREY CLAY
												4.6	11.9	SOFT GREY CLAY
												11.9	15.2	BLUE CLAY, GRAVEL & BOULDERS
												15.2	16.8	CLAY; STREAKS OF SILT
												16.8	19.2	SILT, FINE SAND & SAND
												19.2	23.5	SOFT CLAY WITH SILT
												23.5	24.4	CLAY, GRAVEL & BOULDERS
												24.4	--	BEDROCK
														** SCREENED FROM 17.4 TO 20.4 m **
613	FORD MOTOR CO.: B.F. CON., LOT 1, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	176	JUN 1960	12.7	NA	NA	NA	NA	NA	NA	TEST HOLE	0.0	0.3	TOPSOIL
												0.3	4.6	RED CLAY;STREAKS OF GREY CLAY
												4.6	11.9	SOFT GREY CLAY
												11.9	15.2	BLUE CLAY, GRAVEL & BOULDERS
												15.2	16.8	CLAY; STREAKS OF SILT
614	FORD MOTOR CO.: B.F. CON., LOT 1, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	176	JUL 1960	5.1	22.9	FRESH	24	4.3	5.5	1.9	TEST HOLE	0.0	0.3	TOPSOIL
												0.3	2.7	RED CLAY
												2.7	12.2	BLUE CLAY
												12.2	13.4	CLAY, GRAVEL & BOULDERS
												13.4	14.6	CLAY
												14.6	16.2	CLAY; STREAKS OF SILT
												16.2	18.0	CLAY
												18.0	18.9	SILT; FINE SAND
												18.9	20.7	CLAY
												20.7	21.3	SILT
												21.3	22.9	CLAY
												22.9	26.5	TIGHT SAND; FINE GRAVEL
												26.5	28.4	CLAY & GRAVEL
												28.4	28.6	ROCK
														** SCREENED FROM 24.0 TO 27.1 **

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-27E

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
615	FORD MOTOR CO.: B.F. CON., LOT 3, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	174	JUL 1960	5.1	22.9	FRESH	23.8	3.1	9.1	1.1	TEST HOLE	0.0	0.3	TOPSOIL
												0.3	2.7	BLUE CLAY; RED STREAKS
												2.7	7.9	RED CLAY
												7.9	12.8	SOFT BLUE CLAY
												12.8	13.7	CLAY, GRAVEL & BOULDERS
												13.7	15.2	RED CLAY
												15.2	19.5	CLAY; SOFT GRAVEL STREAKS
												19.5	23.2	CLAY, GRAVEL & BOULDERS
												23.2	24.7	GRAVEL
												24.7	25.3	CLAY & BOULDERS
												25.3	--	ROCK
														** SCREENED FROM 22.9 TO 23.8 m **
616	WARNER, E. B.F. CON., LOT 2, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	180	NOV 1960	15.9	20.4	FRESH	18.9	8.5	8.5	0.8	DOMESTIC	0.0	14.9	BLUE CLAY
												14.9	18.9	GRAVEL
												18.9	20.4	LIMESTONE
617	VALENSTINE, H. B.F. CON., LOT 3, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	176	MAY 1956	15.7	24.1	SULPHUROUS	NA	3.7	5.8	0.9	DOMESTIC	0.0	0.3	TOPSOIL
												0.3	5.2	BROWN CLAY
												5.2	10.1	BLUE CLAY
												10.1	21.3	SAND
												21.3	22.9	CLAY & STONES
												22.9	24.1	GRAVEL
618	WARNER, A B.F. CON., LOT 3, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	179	JAN 1960	12.7	21.3	FRESH	19.8	9.8	11.6	0.8	DOMESTIC STOCK	0.0	7.3	RED CLAY
												7.3	12.2	HARDPAN
												12.2	19.8	BLUE CLAY
												19.8	21.3	LIMESTONE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-22E

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
619	VANALSTINE B.F. CON., LOT 3, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	176	AUG 1960	15.9	30.5	SULPHUROUS	28	5.2	24.4	0.2	DOMESTIC	0.0	0.3	TOPSOIL
												0.3	5.2	BROWN CLAY
												5.2	15.2	BLUE CLAY
												15.2	25.3	SAND
												25.3	28.0	GRAVEL
												28.0	31.4	DARK ROCK
624	LUSTY, W CON. 1, LOT 1, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	179	MAY 1954	15.9	20.4	SULPHUROUS	20.4	4	9.1	0.8	DOMESTIC	0.0	0.3	SANDY LOAM
												0.3	19.5	BLUE CLAY
												19.5	19.8	GRAVEL, LITTLE WATER
												19.8	20.4	LIMESTONE ROCK
												20.4	--	LIMESTONE ROCK, WATER
625	CRUICKSHANK, E. CON. 1, LOT 4, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	179	MAY 1956	15.2	17.1	FRESH	14.6	5.8	7.3	0.6	DOMESTIC STOCK	0.0	0.6	TOPSOIL
												0.6	5.2	BROWN CLAY
												5.2	14.3	BLUE CLAY
												14.3	17.7	BROWN ROCK
1388	OKINCZYE, A. LOT 197, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	179	MAY 1954	14.3	15.8	FRESH	15.5	6.1	13.7	0.9	DOMESTIC	0.0	3.0	HARD CLAY
												3.0	13.7	BLUE CLAY
												13.7	15.2	FINE SAND
												15.2	15.5	GRAVEL & A LITTLE WATER
												15.5	15.8	LIMESTONE ROCK & WATER
1389	AULD, G. LOT 197, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	179	JUN 1954	14.3	15.9	SULPHUROUS	15.2	6.1	13.7	0.9	DOMESTIC	0.0	3.0	HARD CLAY
												3.0	13.7	BLUE CLAY
												13.7	15.2	FINE SAND
												15.2	17.1	LIMESTONE ROCK

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-27E

Sheet 4 of 9

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
1390	DWYER, R. LOT 197, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	179	FEB 1955	15.2	18.3	FRESH	15.2	7.3	9.1	0.5	DOMESTIC	0.0	5.5	BROWN CLAY
												5.5	11.3	BLUE CLAY
												11.3	12.8	SOFT CLAY
												12.8	15.2	CLAY & GRAVEL
												15.2	18.9	DARK ROCK
1391	RIGGS, J.B. LOT 197, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	180	SEP 1956	15.2	16.8	FRESH	16.8	7	8.5	0.6	DOMESTIC	0.0	1.2	FILL
												1.2	4.6	BROWN CLAY
												4.6	9.4	BLUE CLAY
												9.4	14.0	SOFT GREY MUCK
												14.0	16.8	GRAVEL
												16.8	17.4	DARK ROCK
1394	WILSON, L. LOT 206, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	176	JUN 1960	15.2	22	SULPHUROUS	21.9	1.8	2.4	1.4	DOMESTIC	0.0	0.3	TOPSOIL
												0.3	4.9	BROWN CLAY
												4.9	16.3	BLUE CLAY
												16.3	17.4	SAND
												17.4	21.0	CLAY & PEBBLES
												21.0	22.0	GRAVEL
												22.0	22.6	BROWN ROCK
1395	FEENEY, F.B. LOT 206, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	175	JUN 1948	15.2	18.0	SULPHUROUS	17.1	0.9	12.2	0.2	DOMESTIC	0.0	1.2	HARD CLAY
												1.2	16.8	BLUE CLAY
												16.8	18.3	ROCK(LIMESTONE)
1396	MONTROSE MOTEL LOT 210, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	176	APR 1964	16.5	23.8	SULPHUROUS	24.1	5.2	22.9	1.5	COMMER-CIAL	0.0	1.2	SOFT BROWN CLAY
												1.2	19.8	SOFT BLUE CLAY
												19.8	23.5	SOFT BROWN CLAY
												23.5	23.8	COARSE GRAVEL & WATER
												23.8	24.1	LIMESTONE ROCK

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-2?E

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
1397	WARDEN, J. LOT 211, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	177	SEP 1951	15.9	22	FRESH	21.9	6.1	15.2	1.1	DOMESTIC	0.0	3.1	HARD CLAY
												3.1	21.3	BLUE CLAY
												21.3	22.0	GRAVEL & WATER
1398	MONTGOMERY, E. LOT 211, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	177	NOV 1954	15.2	25	FRESH	24.6	5.5	5.5	1.1	DOMESTIC	0.0	1.5	CLAY FILL
												1.5	6.7	BROWN CLAY
												6.7	17.1	BLUE CLAY
												17.1	20.7	SAND
												20.7	24.7	GRAVEL
												24.7	25.3	DARK ROCK
1399	WARDEN, G. LOT 211, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	178	SEP 1956	15.2	24.4	FRESH	23.1	4.9	6.4	0.6	DOMESTIC	0.0	0.3	TOPSOIL
												0.3	4.3	BROWN CLAY
												4.3	12.2	BLUE CLAY
												12.2	21.3	SAND
												21.3	23.2	GRAVEL
												23.2	25.0	BROWN ROCK
1400	WILSON, R. LOT 211, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	178	JUN 1959	17.8	21.2	FRESH	21.3	6.1	13.7	0.6	DOMESTIC	0.0	3.1	HARD BROWN CLAY
												3.1	15.2	BLUE CLAY
												15.2	16.8	MARLY RED SAND
												16.8	18.3	BLUE CLAY
												18.3	21.2	MARLY RED SAND
												21.2	21.3	COARSE GRAVEL
												21.3	21.6	LIMESTONE ROCK
1401	PREDY, C.R. LOT 211, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	179	JUL 1905	16.9	13.4	FRESH	18.6	4.3	19.2	1.5	DOMESTIC	0.0	5.5	HARD CLAY
												5.5	13.4	SANDY CLAY
												13.4	18.6	SAND
												18.6	19.2	LIMESTONE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-22E

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
1402	MONTGOMERY BROS. LOT 211, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	178	MAR 1960	16.9	19.5	FRESH	19.5	3.7	7.6	1.8	DOMESTIC	0.0	2.7	HARD CLAY
												2.7	14.6	SOFT CLAY
												14.6	18.9	SANDY CLAY
												18.9	19.5	HARD SHALE
												19.5	19.8	LIMESTONE ROCK
1403 A.	CARLESSO CONST. CO. LOT 211, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	175	OCT 1964	12.7	23.8	SULPHUROUS	22.9	6.7	22.9	0.6	COMMER-CIAL	0.0	4.9	HARD BROWN CLAY
												4.9	20.7	SOFT BROWN CLAY
												20.7	22.9	HARDPAN, LARGE GRAVEL
												22.9	23.8	LIMESTONE ROCK
2252	STAMFORD SCHOOL BOARD B.F. CON., W.R., LOT 9, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	177	MAY 1954	16.5	28	FRESH	28	4.3	10.7	0.8	PUBLIC	0.0	3.1	HARD CLAY
												3.1	24.4	BLUE CLAY
												24.4	25.3	SMALL STONES
												25.3	25.9	FINE SAND & WATER
												25.9	28.0	COARSE GRAVEL & WATER
												28.0	--	LIMESTONE ROCK
2253	GALLEY, G. B.F. CON., W.R., LOT 10, CITY OF NIAGARA FALLS, (FORMERLY WILLOUGHBY TWP.)	175	MAR 1959	12.7	29	SULPHUROUS	26.5	9.1	11.6	1.5	COMMER-CIAL	0.0	5.5	RED CLAY
												5.5	15.5	BLUE CLAY
												15.5	24.4	SAND
												24.4	26.5	FINE GRAVEL
												26.5	29.0	SHALE
2281	LAKE, N. CON. 6, LOT 12 CITY OF NIAGARA FALLS, . (FORMERLY WILLOUGHBY TWP.)	175	OCT 1956	15.2	19.8	FRESH	20.1	3.7	7.6	1.3	DOMESTIC	0.0	6.1	HARD BROWN CLAY
												6.1	15.2	SOFT BROWN CLAY
												15.2	19.2	SANDY CLAY
												19.2	19.8	SMALL STONES
												19.8	20.1	WATER & COARSE GRAVEL
												20.1	--	LIMESTONE ROCK

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-22E

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2283	STRINKE, T. CON. 6, LOT 12 CITY OF NIAGARA FALLS, (FORMERLY WILLOUGHBY TWP.)	175	JUN 1965	15.9	21.3	FRESH	21.6	3.1	4.6	0.8	DOMESTIC	0.0	9.1	BROWN LOAM
												9.1	19.8	BLUE CLAY
												19.8	21.0	GRAVEL & CLAY
												21.0	21.6	GRAVEL & SHALE
2285	DELL, D CON. 7, LOT 15 CITY OF NIAGARA FALLS, (FORMERLY WILLOUGHBY TWP.)	173	MAR 1947	15.2	26.8	SULPHUROUS	26.8	6.1	9.1	1.9	DOMESTIC STOCK	0.0	4.6	HARD CLAY
												4.6	21.3	BLUE GREY CLAY
												21.3	26.8	ROCK(LIMESTONE)
2286	BOARD OF EDUCATION CON. 7, LOT 16 CITY OF NIAGARA FALLS, (FORMERLY WILLOUGHBY TWP.)	175	JUN 1954	15.9	11	SULPHUROUS	11	3.7	6.1	0.6	PUBLIC	0.0	4.6	HARD CLAY
												4.6	10.1	BLUE CLAY
												10.1	10.4	SAND, GRAVEL & WATER
												10.4	11.0	COARSE GRAVEL & WATER
												11.0	--	LIMESTONE ROCK
2380	PRINC, L. CON. 1, LOT 7 CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	178	NOV 1968	15.9	30.2	SULPHUROUS	22.9	7.6	9.1	0.8	DOMESTIC STOCK	0.0	7.7	BROWN CLAY
												7.7	19.8	BLUE CLAY
												19.8	21.0	BLUE CLAY & STONES
												21.0	22.9	BLUE CLAY & GRAVEL
												22.9	30.5	GREY NIAGARA ROCK
2494	LAFRENIERE, L. CON. 2, LOT 2 CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	178	DEC 1969	15.2	20.1	FRESH	20.1	10.7	13.7	0.6	DOMESTIC	0.0	16.7	BROWN CLAY, PACKED
												16.7	18.9	BLUE CLAY, GRAVEL, HARD
												18.9	19.8	GREY HARDPAN, STONES, HARD
												19.8	20.1	GREY LIMESTONE, LAYERED

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-22E

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2513	BIGGAR, K. B.F. CON., LOT 6 CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	178	APR 1978	15.9	36.6 47.2	SULPHUROUS	34.7	N/A	36.6	0.4	STOCK	0.0	6.7	BROWN CLAY, PACKED
												6.7	20.4	REDDISH CLAY, SOFT,(GAS)
												20.4	34.4	GREY CLAY, GRAVEL, HARD,(GAS)
												34.4	47.8	GREY NIAGARA ROCK, LAYERED
2673	DIRECT WINTERS TRANSP. B.F. CON., W.R., LOT 10, CITY OF NIAGARA FALLS, (FORMERLY WILLOUGHBY TWP.)	178	JUL 1972	15.9	24.7	SULPHUROUS	24.1	7	13.7	0.8	DOMESTIC	0.0	4.6	BROWN CLAY, PACKED
												4.6	23.5	REDDISH CLAY, SILT, SOFT
												23.5	24.1	GREY CLAY, GRAVEL, HARD
												24.1	25.0	GREY LIMESTONE, LAYERED
2921	MANNELL, D. CON. 1, LOT 7, CITY OF NIAGARA FALLS, (FORMERLY CROWLAND TWP.)	178	JUN 1982	15.9	37.8	MINERAL	36.7	6.1	16.8	1.5	STOCK	0.0	21.9	CLAY
												21.9	36.3	BROWN CLAY & STONES & BOULDERS
												36.3	37.8	ROCK
3173	YORK AUTO TRUCK COLL. CON. 6, LOT 12, CITY OF NIAGARA FALLS, (FORMERLY WILLOUGHBY TWP.)	178	JUL 1976	15.9	26.2	MINERAL	23.8	6.7	22.9	0.4	DOMESTIC	0.0	4.9	BROWN CLAY, PACKED
												4.9	22.9	REDDISH CLAY, SOFT
												22.9	23.8	GREY CLAY, SHALE, HARD
												23.8	26.5	GREY LIMESTONE, LAYERED
3359	J & R TOWN SERVICE LOT 205, CITY OF NIAGARA FALLS, (FORMERLY STAMFORD TWP.)	175	JUN 1979	15.9	22.8	SULPHUROUS	21.9	2.1	18.3	0.7	DOMESTIC	0.0	18.0	GREY CLAY
												18.0	21.9	GRAVEL, CLAY
												21.9	22.9	NIAGARA ROCK

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PT-22E

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MO YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
3441	FIORENTINO, L B.F. CON., W.R., LOT 10 CITY OF NIAGARA FALLS, (FORMERLY WILLOUGHBY TWP.)	178	FEB 1981	15.9	21.6	FRESH	21.3	4.9	7.6	1.1	STOCK	0.0	3.7	BROWN CLAY, PACKED
												3.7	13.7	GREY CLAY, DENSE
												13.7	21.0	BROWN CLAY, GRAVEL STONES, PACKED
												21.0	21.6	GREY HARDPAN, LAYERED

8.2 SUMMARY OF OIL AND GAS WELL DATA

No oil and gas well records were available for the study area. The Ministry of Natural Resources (MNR) office in London Ontario provided locations of abandoned oil and gas boreholes from MNR Petroleum Resources Maps (see footnote on the summary sheet). These boreholes have been numbered 1 to 23 (Figure 4). Boreholes 24-28 were noted in discussions with local residents. There is no information available (aside from location) for these boreholes.

All oil and gas well records and mapping are on file.

TABLE 5, SUMMARY OF OIL & GAS WELL DATA

Site: PI-27E
Sheet 1 of 1

WELL BOREHOLE No.	LOCATION location	GROUND ELEVATION (m ASL)	FROM FROM	TO TO	MATERIALS DESCRIPTION	COMMENTS
1-28	-VARIOUS- SEE FIGURE 4 IN POCKET	NA	NA	NA	NA	ABANDONED

Gartner Lee Associates Limited

NOTES: Numbers 1-23 : no data available ,locations obtained from Ministry of Natural Resources, Petroleum Resources Map F-17 (NTS REFERENCE 30M/3 EAST NIAGARA) (Effective Date, February1984).

Number 24-28; no data available, location from residents during field interviews (see Table 6, no.'s 5, 8 and 22).

8.3 SUMMARY OF SITE INTERVIEW (WALK AND TALK) DATA

Water use data from Ecologistic Limited's field interview (Walk and Talk) forms is presented in Figure 8 (in map pocket). Water use data were collected from residents on the site and on adjacent properties.

Water use data were augmented with information collected by Gartner Lee Associates Limited staff during discussions with local interest groups and individuals.

Deeper drilled wells are considered to terminate in bedrock where supporting evidence is available.

Although most of the information was provided in Imperial units, it has been converted to metric units for uniformity with the remainder of the report.

Interview numbers are related to identifications assigned by Ecologistics Limited during the collection of these data.

A copy of the water resources questionnaire form is attached at the end of this section.

Copies of the interview forms are on file.

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site PI-27E Sheet 1 of 11

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
1	Mr. & Mrs. J. Stirling	4 City of Niagara Falls, formerly Crowland TWP.	BF	101-1			✓	Cistern -rainwater, soft water quality -supplies household -dries up 2 to 3 times per year
2.	Mr. Michael Cook	3 City of Niagara Falls, formerly Crowland TWP.	BF	66-1			✓	Cistern -rainwater, soft water quality -supplies household
3	Mr. & Mrs. Barry McGrath	3 City of Niagara Falls formerly Crowland TWP.	BF	68-1	✓		2	Cistern -supplies household, 9000L(2000 gal.) capacity Cistern -unused, 4500L (1000 gal.) capacity Drilled Well (MOE well 619) 36.6m (120 ft.) deep -water quality sulphurous -unused

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
4	Mr. J. Sider	1 City of Niagara Falls, formerly Willoughby TWP.	BF	211-1		✓		Dug/Bored well (no MOE record) -1.8m (6 ft.) deep, 2.4m (8 ft.) wide -supplies household and for watering garden -water trucked in and put in well -water quality soft.
5	Mr. & Mrs. J. Merritt	5 City of Niagara Falls, formerly Crowland TWP.	1	109-1	✓		✓	Cistern -supplies household -rainwater, water quality soft -occasionally dries up, city water occasionally trucked in Drilled well (no MOE record) -30.5m (100 ft.)deep -not used Pond on property Two Oil and Gas wells on property #'s 27 and 28 in Figure 4
6	Mr. Lou Fiorentino	1 City of Niagara Falls, formerly Willoughby TWP.	BF	41-2	2		✓	Drilled Well (MOE well 3441) -supplies household and livestock -water quality hard, sulphurous Drilled Well (no MOE record) -supplies household and livestock -water quality hard, sulphurous -water level got low so another well drilled Cistern -supplies household, used for drinking Bottled water for drinking

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
7	Mr. Don Mannell	7 City of Niagara Falls, formerly Crowland TWP.	1	147-2	✓		✓	Drilled Well (MOE well 2921) -supplies household and livestock -water quality sulphurous Cistern -supplies household
	Mr. Don Mannell	3 City of Niagara Falls, formerly Crowland TWP.	1	147-2				Pond on property -water stagnant
8	Mr. Archie Warner	3 City of Niagara Falls, formerly Crowland TWP	BF	25-2	✓		2	Cisterns (2) -supply household -water quality soft -dry up once every 15 years Drilled Well (MOE well 618) -19.5, (64 ft.)deep -water level 6.7m (22 ft.)from surface -water quality hard, sulphurous Gas/oil well in driveway, well #24 in Figure 4.
9	Mrs. D. Pietrangelo	2 City of Niagara Falls, formerly Crowland TWP.	1	212-1a-1				No water use reported - underground stream reported
		2 City of Niagara Falls, formerly Crowland TWP.	1	212-1a-2				No water use reported - underground stream reported

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
10	Mr. Charles Warner	3 City of Niagara Falls, formerly Crowland TWP.	BF	48-2	✓		✓	Cistern -supplies household -rainwater Drilled Well (no MOE record) -29.0m (95 ft.)deep -water level at 7.6m(25 ft.) -supplies livestock -water quality hard, sulphurous
11	Mr. Harold A. Warner	2 City of Niagara Falls, formerly Crowland TWP	BF	93-1	✓		✓	Drilled Well (MOE well 616) -21.6m (72 ft.)deep -supplies household toilets and outside taps -water quality, hard, high iron content Cistern -supplies household, drinking, washing -rainwater or trucked in city water -never goes dry (see Number 26)
12	Mr. D. Pietrangelo	2 City of Niagara Falls, formerly Crowland TWP.	1	213-1A	✓		✓	Drilled Well (no MOE record) 21.3m(70 ft.)deep -household use -water quality excellent Cistern -household use -soft water quality -dries up every couple of weeks Pond -supplies livestock

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
13	Mr. & Mrs. Edward F. Hamilton	1 City of Niagara Falls, formerly Crowland TWP.	1	529-G	✓		✓	Drilled Well (no MOE record) -18.3, (60 ft.)deep -water quality salty,not drinkable Cistern -supplies household -water purchased Pond -3.7 m (12 ft) deep -supplies animals
14	Mr. Tibor Palatine	12 City of Niagara Falls, formerly Willoughby TWP.	6	284	✓			Drilled Well (no MOE record) -23.8m (78 ft.) deep -water level at 5.5m (18 ft.) -supplies household and livestock -water quality hard, clean, not sulphurous
15	Mr. John Grassl	1 City of Niagara Falls, formerly Crowland TWP.	BF	183				On municipal water supply
16	GLAL Field Notes	1 City of Niagara Falls, formerly Crowland TWP.	BF	-				Building Removed - No known water use

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
17	GLAL Field Notes	1 City of Niagara Falls, formerly Crowland TWP.	BF	-				Building Removed-No known water use
18	GLAL Field Notes	4 City of Niagara Falls, formerly Crowland TWP.	BF	-				Farm Buildings only no residence; no known water use
19	GLAL Field Notes	1 City of Niagara Falls, formerly Crowland TWP.	BF	-				No Residence on site; no known water use
20	GLAL Field Notes	1 City of Niagara Falls, formerly Crowland TWP.	1	-	(✓)			Hungarian Hall reportedly has a new water well, unknown well type
21	Mr. Ken Biggar	6 City of Niagara Falls, formerly Crowland TWP.	BF	13-2	✓		✓	Cistern supplies household Drilled Well (MOE well 2513) -45.7m (156 ft.)deep -supplies livestock -water quality sulphurous

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
22	GLAL Field Notes	5 City of Niagara Falls formerly Crowland TWP.	2	-				2 abandoned oil and gas wells, well #'s 25 and 26 in Figure 4
23	N. Lambert	206 City of Niagara Falls		SLSA Well Survey 1968		✓		Dug/Bored well (no MOE record) -3.4m (11 ft.) deep -water level 3.1m(10 ft.) from surface -supplies household and livestock -SLSA well 3512
24	Kneller	7 City of Niagara Falls Crowland TWP.	BF	SLSA Well Survey 1968		✓		Dug/Bored well (no MOE record) -4.9m (16 ft.)deep -water level 1.7 m, (5.7 ft) from surface -supplies household -water quality sulphurous -SLSA well 3513
25	Dumele	4 City of Niagara Falls formerly Crowland TWP.	2	SLSA Well Survey 1968		✓		Dug/Bored well (no MOE record) -3.1m (10 ft.) deep -water level 1.4m (4.5 ft.)from surface -supplies household and livestock -has never gone dry -SLSA well 3509

Table 6 SUMMARY OF SITE INTERVIEW DATA

Site PI-27E Sheet 8 of 11

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
26	A. Warner	1 & 2 City of Niagara Falls formerly Crowland TWP.	BF	SLSA Well Survey 1968	✓		✓	Drilled well (MOE well 616) - 19.8m (65 ft.)deep -completed into bedrock -water level 7.3m (24 ft.) from surface -supplies household and livestock -water quality hard,sulphurous -has never gone dry -SLSA well 3519 Cistern supplies household (see Number 11)
27	L.Pramc	7 City of Niagara Falls formerly Crowland TWP.	1	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -32.0m (105 ft.) deep -completed into bedrock -water level 7.0m (23 ft.) from surface -supplies livestock -has never gone dry -SLSA well 3520
28	J. Taylor	7 City of Niagara Falls formerly Crowland TWP.	2	SLSA Well Survey 1968		✓		Dug well (no MOE record) -3.4m (11 ft.) deep -water level 2.3m (7.6 ft.)from surface -supplies household -water quality not sulphurous -has gone dry -SLSA well 3530 (See Number 38)

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
29	W. McCredie	13 City of Niagara Falls formerly Willoughby TWP.	7	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -36.6m (120 ft.)deep -water level 4.9m(16 ft.) from surface -supplies livestock -water quality hard.sulphurous -SLSA well 3531
30	N/A	6 City of Niagara Falls formerly Crowland TWP.	BF	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -completed into bedrock -SLSA well no.4006
31	N/A	4 City of Niagara Falls formerly Crowland TWP.	BF	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -completed into overburden -SLSA well no.4115
32	N/A	1 City of Niagara Falls formerly Crowland TWP.	1	SLSA Well Survey 1968	✓			Drilled well (MOE well 624) -completed into bedrock -SLSA well No.4159
33	N/A	7 City of Niagara Falls formerly Crowland TWP.	1	SLSA Well Survey 1968	✓			Drilled well (MOE well 2380) -completed into bedrock -SLSA well no.4024

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
34	N/A	1 City of Niagara Falls formerly Crowland TWP.	2	SLSA Well Survey 1968	✓			Drilled well (no MOE record) -completed into bedrock -SLSA well no.4160
35	J. Horton	6 City of Niagara Falls formerly Crowland TWP.	1	SLSA Well Survey 1968	✓		✓	Drilled well (no MOE record) -33.8m (111 ft.)deep -completed into bedrock -water level 7.0m (23 ft.) from surface -supplies livestock -water quality hard,sulphurous -has never gone dry -SLSA well 3519 Cistern supplies household
36	Frontier Auto Dismantlers	7 City of Niagara Falls formerly Crowland TWP.	2	24-1	✓			Drilled well (no MOE record) -27.4m (90 ft.)deep -domestic use -water quality, sulphurous
	Frontier Auto Dismantlers	7 City of Niagara Falls	2	GLAL Field Visit				-hit gas at 13.7m (45 ft.) -water found at 19.8m (65 ft.) -completed into bedrock -well yield 0.4-0.8L/sec(5-10GPM)
37	Mr. Ernest Damore	5 City of Niagara Falls formerly Crowland TWP.	2	28-1	✓			Drilled well (no MOE record) -50.3m (165 ft.) deep -driven casing -supplies household

Table 6 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
38	Mr. & Mrs. John Taylor	7 City of Niagara Falls formerly Crowland TWP.	2	111-1		✓		Dug/Bored well (no MOE record) -7.6m (25 ft.) deep (GLAL field info.) -water level approx. 3m (10 ft.) from surface (GLAL field info.) -supplies household -water quality hard,sulphurous -dries up sometimes -trucks in water occasionally and fills well Pond on property (see Number 28)
39	Mr. A. Delvecchio	7 City of Niagara Falls,formerly Crowland TWP.	1	267-1				No known water supply on property, vacant land.
40	Mr. & Mrs. B. Cowan	6 City of Niagara Falls,formerly Crowland TWP.	1					No information available
41	Mr. Chas Warner	3 City of Niagara Falls formerly Crowland TWP.	2	48.2	✓		✓	Cistern supplies household -rainwater -goes dry 12 times per year Drilled well (no MOE record) -29.0m (95 ft.)deep -water level 7.6m (25 ft.) from surface -supplies livestock -water quality sulphurous

Interview Identification Number: _____

PHYSICAL RESOURCES - WATER

We are interested in the water used on this property: where it comes from, its quality, and how much you use.

1. What is this household's source of supply for domestic water? (e.g., drinking, laundry, toilet)

drilled water	☐	Locate on map with symbol Dr-H
dug wells	☐	Locate on map with symbol Du-H
stream water	☐	Locate on map with symbol *SW-H
cistern	☐	Locate on map with symbol *C-H
bottled water	☐	
municipal main	☐	
other, specify		_____

2. What is the water supply for the livestock and irrigation on this property?

drilled wells	☐	Locate on map with symbol Dr-A
dug wells	☐	Locate on map with symbol Du-A
streams or dams	☐	Locate on map with symbol *SW-A
cisterns	☐	
municipal main	☐	
other (e.g., ponds)		_____

3. Are there any streams or ponds on your property?

streams	Yes ☐	No ☐
ponds	Yes ☐	No ☐

4. What can you tell us about the quality of the water

a) you use or drink? (hard, soft, sulphurous, iron, salty, etc.) _____

_____

_____

b) in the streams or ponds? _____

_____

_____

5. Do the wells, cisterns or streams that you use for water supply ever go dry? If so, how often? _____

_____

_____

_____

Interview Identification Number: _____

6. Can you tell us anything about the construction of the wells? (e.g., when they were drilled, depth, type of pump, name of the driller) _____

7. Has any portion of your property been filled or excavated? If so, please show where on the map. (Locate on map with symbol EV.)

8. Do you know where there are any gas or oil wells on your property or the property you farm - in use or abandoned? Please show their locations on the map with the symbol GW.

9. Please tell us about any problems with flooding in the creeks and streams on your property. Please show locations of the flooded areas on the map. (Locate with symbol FA.)

8.4 BOREHOLE LOGS

8.4.1 GARTNER LEE ASSOCIATES LIMITED BOREHOLE LOGS, 1984
- SITE PI-27E
- SITE LF-1E

8.4.2 SUMMARY OF MINISTRY OF TRANSPORTATION AND COMMUNICATIONS (MTC) BOREHOLE DATA

8.4.3 SUMMARY OF CITY OF NIAGARA FALLS (CNF) BOREHOLE DATA

8.4.4 ST. LAWRENCE SEAWAY AUTHORITY BOREHOLE LOGS

8.4.1 GARTNER LEE ASSOCIATES LIMITED BOREHOLE LOGS, 1984

Borehole locations are shown in Figure 4 (in map pocket).

Borehole logs are based on field notes which have been verified by the project geologist following re-examination of the samples.

Continuous samples were obtained by advancing a large split tube (8.9 cm x 152 cm) through the hollow stem augers.

Standard penetration tests were performed at 1.5 m intervals and water contents were measured in samples taken from the 'nose-piece' of the standard split spoon sampler.

Textural descriptions are provided for each geologic unit and each deposit is named (in brackets) to indicate its origin.

All material descriptions are based on visual hand sample examination and no laboratory grain size analyses were performed. Textural descriptions are provided under 'Particle Size Classification System' in the Glossary of Selected Terms, Section 8.6.

Borehole elevations are estimated from the 1:10 000 scale base map contours. All elevations are above sea level (ASL) and are estimated to the nearest metre.

The term pebble has been used to describe gravel-sized rock particles within a fine grained matrix.

GEOTECHNICAL NOTES AND ABBREVIATIONS

Standard Penetration Resistance 'N' - The number of blows required to advance a standard split spoon sampler 30 cm into the subsoil, driven by means of a 63.5 kg hammer falling freely a distance of 75 cm.

The consistency of cohesive soils and the relative density or denseness of cohesionless soils are described as follows:

Consistency	'N' Blows per 0.3 m	Denseness	'N' Blows per 0.3 m
Very soft	0-2	Very Loose	0-4
Soft	2-4	Loose	4-10
Firm	4-8	Compact	10-30
Stiff	8-15	Dense	30-50
Very Stiff	15-30	Very Dense	> 50
Hard	> 30		

ABBREVIATIONS

WTPL - Wetter than Plastic Limit

DTPL - Drier than Plastic Limit

APL - About Plastic Limit

Wp - Plastic Limit

WL - Liquid Limit

SS - Split Spoon Sample

T - Split Tube Sample

SITE PI-27E

BOREHOLE NO. GL 1 (27E)

PROJECT NAME Phase 4A Drilling And Sampling

CLIENT Ontario Waste Management Corporation **DATE** September 12, 1984

BOREHOLE TYPE 108 mm I.D.Hollow Stem Auger ,Continuous Sampling **GEOLOGIST** A.B./A.C.

GROUND ELEVATION 177 m. (Approximate) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.3	TOPSOIL: Very dark brown clayey silt topsoil with organics and roots								
	CLAYEY SILT TO SILTY CLAY: brown to dark grey clayey silt to silty clay, heavily weathered to 1.3 m, silt dominant from ±6.0 m to ±12.0 m, generally well laminated with occasional massive zones, occasional small (<1 cm) pebble brown/grey colour change at ±3.4 m, grey - carbonate infilling in fractures to 2.8 m, firm to very stiff, DIPL to 1.6 m, APL 1.6 to 3.6 m, WTPL below 3.6 m (Upper Glaciolacustrine Unit)			1	SS	20	25		NO SAMPLE
				2	SS	10	N/A		
				3	SS	8	23		
	3 silt to fine sand laminae to 1 cm thick showing brown rusty staining (6.3 to 6.6 m)			4	SS	6	27		
				5	SS	4	27		
				6	SS	5	26		
				7	SS	4	27		
	becomes massive to indistinctly laminated, increasing pebble and clay content (±12 m)			8	SS	7	20		
				9	SS	9	20		
				10	SS	8	23		
				11	SS	10	21		
18.0									
	SILTY CLAY TO CLAYEY SILT TILL: brown silty clay to clayey silt till with pebbles to 2 cm, massive to indistinctly laminated, upper and lower contacts gradational, stiff, WTPL (Halton Till)			12	SS	10	21		
19.3				13	SS	7	42		42
	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, laminated, occasional silt lamina to 1 mm, occasional pebbles to 1 cm, material below 24.1 m disturbed, silty fine sand with possible silt till, soft to firm, WTPL (Lower Glaciolacustrine Unit)			14	SS	3	35		
				15	SS	7	39		
24.8				16	SS	7	18		

Gartner Lee Associates Limited

BOREHOLE NO. GL 1 (27E) (cont'd)

PROJECT NAME Phase 4A Drilling And Sampling

CLIENT Ontario Waste Management Corporation **DATE** September 12, 1984

BOREHOLE TYPE 108 mm, I.D. Hollow Stem Auger, Continuous Sampling **GEOLOGIST** A.B./A.C.

GROUND ELEVATION 177 m (approximate) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (WP 10 20 30 WL) COMMENTS
26.1	SILT TO SANDY SILT TILL: brown silt to sandy silt till, numerous broken pieces of vuggy fine-grained dolostone, saturated, very dense (Lower Till)			17	SS	*	5	* 75/0.15 m	
	DOLOSTONE: light to medium grey, fine grained dolostone, banded with shale partings, occasional small vugs to 0.5 cm, white gypsum present along some shale partings (to 2 mm thick) and in some vugs (Guelph Formation)								
31.1	Borehole Terminated 31.1 m in dolostone								

BOREHOLE NO. GL 2 (27E)

PROJECT NAME Phase 4A Drilling And Sampling

CLIENT Ontario Waste Management Corporation **DATE** September 7, 1984

BOREHOLE TYPE 108 mm. I.D.Hollow Stem Auger, Continuous Sampling **GEOLOGIST** A.B./A.C.

GROUND ELEVATION 180 m. (approximate) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) COMMENTS
0.4	TOPSOIL: very dark greyish brown clayey silt, numerous roots								
	SILTY CLAY TO CLAYEY SILT: dark grey to brown silty clay to clayey silt, laminated with occasional silt lamina to 1 mm, occasional small (<1 cm) pebbles, upper ±1.1 m heavily weathered with grey lined fracture traces, silt zone 1.8 to 2.0 m, mainly clayey silt 8.5 m to 10.0 m, soft to stiff, APL 0 to 1.9 m, WTPL below 1.9 m (Upper Glaciolacustrine Unit)			1	SS	5	28		
				2	SS	9	23		
				3	SS	5	24		
				4	SS	5	24		
				5	SS	7	23		
				6	SS	2	26		
10.0	SILTY CLAY TO CLAYEY SILT TILL: brown silty clay to clayey silt till with pebbles, massive to indistinctly laminated, disturbed silty fine sand inclusion at 11.3 m (maximum 20 cm thick), upper and lower contacts gradational, firm WTPL (Halton Till)			7	SS	6	22		
				8	SS	4	20		
13.5	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, laminated, occasional silt lamina to 2 mm, occasional small (<1 cm) pebbles, WTPL (Lower Glaciolacustrine Unit)			9	SS	4	25		
14.3	SILT TO SANDY SILT TILL: brown silt to sandy silt till, variable with inclusions of clayey silt, numerous broken pebbles, numerous pebbles in lower portion, lower contact gradational over 1.5 m to bedrock, saturated, compact to very dense (Lower Till)			10	SS	19	12		
				11	SS	60	7		
17.6	DOLOSTONE: medium grey, fine-grained dolostone with shale partings, occasional gypsum (to 3 mm thick) along shale bedding planes (maximum 0.5 cm thick), occasional vugs. (Guelph Formation)			12	SS	*	N/A	* 80/0.10 m	NO SAMPLE
20.9	Borehole terminated at 20.9 m in dolostone.								

Gartner Lee Associates Limited

BOREHOLE NO. GL 3 (27E)

PROJECT NAME Phase 4A Drilling And Sampling

CLIENT Ontario Waste Management Corporation **DATE** September 10, 1984

BOREHOLE TYPE 108 mm I.D.Hollow Stem Auger, Continuous Sampling **GEOLOGIST** E.J.K./A.C.

GROUND ELEVATION 176 m. (approximate) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
	SILTY CLAY TO CLAYEY SILT: brown to dark greyish brown silty clay to clayey silt, heavily fractured and weathered to 0.3 m, numerous silt laminae (to 30% of core volume) to 1.8 m, 1.8 to 6.3 m clayey silt to silty clay, laminated with occasional thin (to 1 mm) silt laminae, occasional pebbles (to 1 cm), 1 cm thick silt lamina with rusty brown stain at 4.4 m firm to hard, APL to 4.1 m, WTPL 4.1 m to 6.3 m (Upper Glaciolacustrine Unit)			1	SS	33	22		
				2	SS	19	26		
				3	SS	6	28		
6.3				4	SS	4	24		
	SILTY VERY FINE SAND TO SANDY SILT: brown to reddish brown silty very fine sand to sandy silt, laminated to massive, occasional pebbles to 2 cm, occasional silt laminae, silty clay to clayey silt 7.2 to 7.6 m and 11.4 to 11.7 m, compact to very dense, saturated (Upper Glaciolacustrine Unit)			5	SS	13	15		
				6	SS	*	16	* 75/0.10 m	
				7	SS	*	36	* 82/0.15 m	
11.9				8	SS	15	18		
	SILT TO CLAYEY SILT TILL: brown silt to clayey silt till, with pebbles to 5 cm, massive to laminated, gradational upper and lower contacts, very stiff, WTPL (Halton Till)			9	SS	26	22		
14.3									
	FINE TO MEDIUM SAND: grey to reddish brown fine to medium sand with reddish brown silt, occasional stones (<3 cm), loose to very dense (Lower Glaciolacustrine Unit)			10	SS	7	N/A		NO SAMPLE
				11	SS	59	18		
				12	SS	34	14		
				13	SS	33	22		
				14	SS	35	19		
				15	SS	58	13		
25				16	SS	80	10		

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BOREHOLE NO. G1 3 (27E) (cont'd)

PROJECT NAME Phase 4A Drilling And Sampling

CLIENT Ontario Waste Management Corporation **DATE** September 7, 1984

BOREHOLE TYPE 108 mm I.D.Hollow Stem Auger, Continuous Sampling **GEOLOGIST** E.J.K./A.C.

GROUND ELEVATION 176 m. (approximate) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) Wp Wl / COMMENTS
25	FINE TO MEDIUM SAND: (continued)			17	SS	76	9		
				18	SS	72	6		
29.8									
	SILT TILL: brown silt till, saturated, very dense (Lower Till)			19	SS	83	8		
30.3	Borehole terminated at 30.3 m in till.								

BOREHOLE NO. GL 4 (27E)

PROJECT NAME Phase 4A Drilling And Sampling

CLIENT Ontario Waste Management Corporation **DATE** September 14, 1984

BOREHOLE TYPE 108mm I.D.Hollow Stem Auger, Continuous Sampling **GEOLOGIST** E.J.K./A.C.

GROUND ELEVATION 178 m. (approximate) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; WP; WL)
0.2	TOPSOIL: very dark grey clayey silt topsoil with roots and vegetation								
	SILTY CLAY TO CLAYEY SILT: dark greyish brown to reddish brown silty clay to clayey silt, well laminated with occasional silt laminae to 2 mm or larger as noted, occasional pebbles to 2 cm, heavily weathered and fractured to ±1 m, colour change observed at ±2.7 m, fractures with grey carbonate infilling and/or rusty discolouration observed 3.0 to 3.4 m, 3.6 to 3.8 m, 4.6 m and 5.1 m, soft to very stiff, WTPL 0 to 0.5 m, APL 0.5 to 2.5 m, WTPL below 2.5 m (Upper Glaciolacustrine Unit)			1	SS	26	21		
				2	SS	14	28		
				3	SS	6	12		
				4	SS	5	26		
8.6				5	SS	3	21		
	SILTY CLAY TO CLAYEY SILT TILL: brown silty clay to clayey silt till, massive to laminated with pebbles and silt or clay clasts, firm to hard, WTPL (Halton Till)			6	SS	23	22		
				7	SS	7	22		
				8	SS	7	20		
				9	SS	7	21		
16.2				10	SS	84	10		
	SILTY FINE SAND: grey to reddish brown silty fine to very fine sand, occasional zones of sandy silt and clayey silt, occasional pebbles to 4 cm, occasional clay clasts to 1 cm, medium to coarse sand dominant below ±25 m, compact to very dense, saturated (Lower Glaciolacustrine Unit)			12	SS	68	8		
				13	SS	95	17		
				14	SS	10	30		
	- Gas at 22.5 m			15	SS	20	20		
25				17	SS	43	12		

BOREHOLE NO. GL 4 (27E) (cont'd)

PROJECT NAME Phase 4A Drilling And Sampling

CLIENT Ontario Waste Management Corporation **DATE** September 14, 1984

BOREHOLE TYPE 108 mm I.D.Hollow Stem Auger, Continuous Sampling **GEOLOGIST** E.J.K./A.C.

GROUND ELEVATION 178 m. (approximate) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) COMMENTS
25	SILTY FINE SAND: (cont'd)			18	SS	49	16		
				19	SS	57	11		
				20	SS	100	7		
				21	SS	*	N/A	* 75/0.02 m	NO SAMPLE
30.4	- Gas at 30.4 m								
	Borehole Terminated at 30.4 m in silty fine sand on a boulder								

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BOREHOLE NO. GL 5 (27E)

PROJECT NAME Phase 4A Drilling And Sampling

CLIENT Ontario Waste Management Corporation **DATE** September 12, 1984

BOREHOLE TYPE 108 mm I.D.Hollow Stem Auger,Continuous Sampling **GEOLOGIST** E.J.K./A.C.

GROUND ELEVATION 178 m. (approximate) **PROJECT NO.** 4A

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) WP WL / COMMENTS
0.2	FILL: slag and silty fill (till)								
0.4	TOPSOIL: very dark brown silty clay to clayey silt topsoil with organics and roots			1	SS	19	22		
	CLAYEY SILT TO SILTY CLAY: dark grey to brown clayey silt to silty clay, laminated with occasional silt lamina to 2 mm, heavily weathered to ±1 m, numerous fractures with grey carbonate infilling to 2.4 m, brown/grey colour change at ±3.7 m, occasional pebbles (to 1 cm), 8 fractures with rusty brown stain between 4.0 and 5.1 m brown stained fractures at 5.9m and 6.4 m, unstained silt lamina (0.5 cm thick) at 14.2 m, firm to hard, DTPL to 4.1 m, WTPL below 4.1 m (Upper Glaciolacustrine Unit)			2	SS	37	23		
				3	SS	12	33		
				4	SS	16	21		
				5	SS	22	24		
				6	SS	7	23		
				7	SS	10	26		
				8	SS	10	24		
	SILT TILL: brown sandy to clayey silt till, pebble content variable, massive to indistinctly laminated (Halton Till)			9	SS	N/A	22		
15.7	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, laminated with silt layers to 0.5 cm occasional pebbles to 1 cm (Lower Glaciolacustrine Unit)			10	SS	18	22		
16.5									
16.7	SANDY SILT TILL: brown sandy silt till, saturated, very dense (Lower Till)			11	SS	54	6		
17.4									
18.7	DOLOSTONE: light to medium grey, fine-grained dolostone with occasional shale partings to 4 mm, occasional vugs comprise up to 10% of volume (Guelph Formation)								
	Borehole terminated at 18.7 m in dolostone								

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SITE LF-1E

BOREHOLE NO. GL 2 (1E)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE September 20/84

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling GEOLOGIST EJK/AC

GROUND ELEVATION 181 m (approximate) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: very dark greyish brown clayey silt topsoil, occasional roots								
	SILTY CLAY TO CLAYEY SILT: brown to dark greyish brown silty clay to clayey silt, generally laminated with massive zones, silt laminae to 2 mm are common, occasional small (<1 cm) pebble, occasional silt or clay clasts to 1 cm, heavily weathered and fractured in upper ±1 m, discoloured fractures at 2.5 m, 3.0 m, 4.8 m, 5.5 m, 7.0 m, discoloured silt laminae at 5.4 m and 6.0 to 6.3 m, very stiff, APL to 4.0 m, WTPL below 4.0 m (Upper Glaciolacustrine Unit)			1	SS	28	22		
				2	SS	26	20		
				3	SS	30	23		
				4	SS	22	21		
				5	SS	26	24		
				6	SS	19	21		
				7	SS	16	20		
11.7	CLAYEY SILT TO SANDY SILT TILL: brown clayey silt to sandy silt till, variable, with several till-like sub-units, massive to laminated, inclusions of silt and silt till, very stiff to hard, WTPL (Halton Till)			8	SS	26	13		
				9	SS	24	9		
	BOULDER @ 15.7 m			10	SS	18	11		
				11	N/A	N/A	N/A		
				12	NA	N/A	N/A		
				13	SS	49	14		
				14	SS	41	8		
20.9	SILTY CLAY TO CLAYEY SILT: brown silty clay to clayey silt, well laminated with red and grey banding, occasional silt lamina to 3 mm, occasional small pebble (to 1 cm) occasional silt or clay clasts (to 1 cm), stiff, WTPL (Lower Glaciolacustrine Unit)			15	SS	13	27		
23.4				16	SS	N/A	29		
	SANDY SILT TO SILTY SAND TILL: dark greyish brown sandy silt to silty sand till, increasing gravel downward (Continued)			17	SS	*	14	* 70/0.38 m → Auger refusal 24.22	

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BOREHOLE NO. GL 2 (1E) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE September 20/84

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling GEOLOGIST EJK/AC

GROUND ELEVATION 181 m (approximate) PROJECT NO. 84-S18 3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
	SANDY SILT TO SILTY SAND TILL: (continued) numerous broken shale fragments, occasional white gypsum pebbles, very dense, saturated (Lower Till)								
27.1	SHALE: medium grey dolomitic shale to shaly dolostone, massive to finely bedded, approximately one quarter of core is white gypsum nodules (Salina Formation)			19	SS	*	9	* 80/0.14 m →	BOULDER
28.3	Borehole terminated at 28.3 m in shale								

BOREHOLE NO. GL 3 (1E)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE September 19/84

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling GEOLOGIST EJK/AC

GROUND ELEVATION 180 m (approximate) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.1	TOPSOIL: very dark grey clayey silt topsoil, roots, organics and twigs								
	CLAYEY SILT TO SILTY CLAY: dark grey to brown clayey silt to silty clay, laminated with massive zones, occasional silt lamina to 2 mm, occasional pebbles to 1 cm, occasional silt or clay clasts to 1 cm, heavily weathered and fractured in upper ±1 m, fractures with discolouration occur at 1.8 m and 6.3 m, silt laminae with discolouration occur at 3.2 to 4.2 m, 4.3 to 4.5 m, 4.8 to 5.6 m and 6.3 m, firm to very stiff, APL to 3.6 m, WTPL below 3.6 m (Upper Glaciolacustrine Unit)			1	SS	24	23		
				2	SS	14	20		
				3	SS	11	23		
				4	SS	10	24		
				5	SS	7	24		
				6	SS	6	24		
				7	SS	12	26		
12.7	CLAYEY SILT TO SILT TILL: brown clayey silt to silt till, massive to indistinctly laminated, very stiff, WTPL (Halton Till)			8	SS	10	25		
14.2				9	SS	27	17		
	SANDY SILT TILL: brown sandy silt till, numerous large pebbles and cobbles to maximum sample size, very dense, saturated (Lower Till)			10	SS	*	N/A	* 30/0.02 m →	BOULDER
				11	SS	*	7	* 50/0.08 m →	BOULDER
17.8	Borehole terminated at 17.8 m in till (probable boulder) gas encountered at 17.8 m								

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8.4.2 MINISTRY OF TRANSPORTATION AND COMMUNICATIONS (MTC) BOREHOLE DATA

Borehole locations are shown in Figure 4 (in map pocket).

Borehole logs are summarized from geologic and geotechnical descriptions in log and cross-section form. All measurements have been converted to metric units.

Borehole elevations are provided to the nearest tenth of a foot in the original data. Elevations have been rounded to the nearest metre in Figure 4.

Copies of borehole records, cross-sections and reports were supplied by the Ministry of Transportation and Communications office at Downsview, Ontario from their GEOCRESS data system and are on file.

8.4.2, SUMMARY OF MINISTRY OF TRANSPORTATION AND COMMUNICATIONS (MTC) BOREHOLE DATA

Site: PI-27E

MTC BOREHOLE No.	LOCATION	GROUND ELEVATION (m ASL)	FROM	TO	MATERIALS DESCRIPTION	COMMENTS
23-1	CON. 7, LOT 15, CITY OF NIAGARA FALLS, MTC #WP 158-64-2	177	0.0	4.6	SILTY CLAY WITH SOME SAND	VERY STIFF TO HARD
			4.6	19.1	SILTY CLAY WITH TRACE TO SOME SAND & SCATTERED GRAVEL	FIRM TO STIFF
			19.1	25.9	SILTY FINE SAND WITH A TRACE OF CLAY	DENSE TO VERY DENSE
			25.9	29.8	SILTY SAND & GRAVEL WITH A TRACE OF CLAY & COBBLES (SANDY TILL)	VERY DENSE
23-2	CON. 7, LOT 15, CITY OF NIAGARA FALLS, MTC #WP 158-64-2	175	0.0	3.8	SILTY CLAY WITH SOME SAND TRACE OF GRAVEL & SOME FINE SILT PARTINGS	STIFF TO HARD
			3.8	12.2	SILTY CLAY WITH SOME SAND AND A TRACE OF GRAVEL	FIRM TO STIFF
			12.2	15.4	SILT WITH SOME SAND & A TRACE OF CLAY	COMPACT
			15.4	19.2	SILTY CLAY WITH SOME SAND & A TRACE OF GRAVEL	STIFF TO VERY STIFF
			19.2	25.0	SILTY SAND WITH A TRACE TO SOME CLAY	COMPACT TO VERY DENSE
			25.0	26.2	SILTY SAND WITH SOME GRAVEL & A TRACE OF CLAY (SANDY TILL)	COMPACT TO VERY DENSE
24-1	B.F.CON..LOT 10, CITY OF NIAGARA FALLS, MTC #WP 300-59-1	180	0.0	3.2	FILL; CLAY WITH SOME TRACE OF SAND & GRAVEL WITH ORGANICS	FIRM TO STIFF
			3.2	10.5	CLAY WITH TRACE ORGANICS IN UPPER PART	STIFF TO VERY STIFF
			10.5	17.7	CLAY	SOFT TO FIRM
			17.7	20.4	SILT	STIFF
24-2	B.F.CON.,LOT 10, CITY OF NIAGARA FALLS, MTC #WP 300-59-1	176	0.0	3.7	FILL; CLAY	FIRM TO STIFF
			3.7	7.3	CLAY WITH TRACE ORGANICS IN TOP LAYER	STIFF TO VERY STIFF
			7.3	15.4	CLAY	SOFT TO FIRM
			15.4	16.9	SILT	DENSE

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NOTE: BOREHOLES 23-1, 23-2 SUMMARIZED FROM BOREHOLE LOGS.
BOREHOLES 24-1, 24-2, 24-3, 24-4 AND 34-1 SUMMARIZED FROM GEOLOGIC CROSS SECTION

8.4.2, SUMMARY OF MINISTRY OF TRANSPORTATION AND COMMUNICATIONS (MTC) BOREHOLE DATA

Site: PI-27E

Sheet 2 of 2

MTC BOREHOLE No.	LOCATION	GROUND ELEVATION (m ASL)	FROM	TO	MATERIALS DESCRIPTION	COMMENTS
24-3	B.F.CON.,LOT 10, CITY OF NIAGARA FALLS. MTC #WP 300-59-1	172	0.0	2.7	CLAY WITH TRACE ORGANICS IN UPPER LAYERS	STIFF TO VERY STIFF
			2.7	14.3	CLAY	SOFT TO FIRM
			14.3	15.7	SILT	DENSE
24-4	B.F.CON.,LOT 10, CITY OF NIAGARA FALLS MTC #WP-300-59-1	181	0.0	8.4	FILL; CLAY	FIRM TO STIFF
			8.4	11.0	CLAY WITH TRACES ORGANICS IN UPPER LAYERS	STIFF TO VERY STIFF
			11.0	18.9	CLAY	SOFT TO FIRM
			18.9	20.1	SILT	STIFF
25	CON. 1, LOT 10, CITY OF NIAGARA FALLS, (PREV. WILLOUGH BY TWP). MTC #64-F-286M	177			REPORT ONLY	
34-1	CON. 1, LOT 15, CITY OF NIAGARA FALLS MTC #WP-300-59-1	177	0.0	18.9	SILTY CLAY, TRACE TO SOME SAND	DENSE TO VERY DENSE
			18.9	25.9	SILTY SAND, TRACE CLAY	DENSE TO VERY DENSE
			25.9	30.5	SILTY SAND & GRAVEL TO CLAYEY SILT + SAND (TILL)	VERY DENSE TO HARD

8.4.3 SUMMARY OF CITY OF NIAGARA FALLS (CNF) BOREHOLE DATA

Borehole locations are shown in Figure 4 (in map pocket).

Borehole data are summarized from geologic and geotechnical descriptions which are in cross-section form and which were supplied by the Regional Municipality of Niagara. All measurements have been converted to metric units.

Borehole elevations are provided to the nearest tenth of a foot in the original data. Elevations have been rounded to the nearest metre in Figure 4.

8.4.3, SUMMARY OF CITY OF NIAGARA FALLS (CNF) BOREHOLE DATA

Site: PI-27E

Sheet 1 of 1

CNF BOREHOLE No.	LOCATION location	GROUND ELEVATION (m ASL)	FROM	TO	MATERIALS DESCRIPTION	COMMENTS
CNF1	B.F.CON.,LOT 10 CITY OF NIAGARA FALLS (PREV. WILLOUGHBY TWP., MONTROSE BRIDGE)	174	0	2.5	MIXED FILL, ORGANIC SILTY CLAY	
			2.5	8.2	SILTY CLAY WITH SILT LAYERS	
			8.2	13.1	SILTY CLAY, SOFT	
			13.1	18.2	SILTY CLAY TILL	
			18.2	22.8	FINE TO VERY FINE SAND	
			22.8	24.3	BEDROCK	
CNF2	B.F.CON.,LOT 10 CITY OF NIAGARA FALLS (PREV. WILLOUGHBY TWP.,MONTROSE BRIDGE)	166	0.0	0.7	ORGANIC ALLUVIUM	RIVER BOTTOM 4.5m BELOW WATER LEVEL BOREHOLE MEASUREMENTS TAKEN FROM RIVER BOTTOM
			0.7	5.6	SILTY CLAY,SOFT	
			5.6	10.7	SILTY CLAY, STIFF TO HARD (TILL)	
			10.7	14.8	FINE TO VERY FINE SAND	
CNF3	LOT 210, CITY OF NIAGARA FALLS (PREV. STAMFORD TWP.. MONTROSE BRIDGE)	167	0.0	5.0	SILTY CLAY, SOFT	RIVER BOTTOM AT 4.0 m BELOW RIVER LEVEL WITH BOREHOLE MEASUREMENTS FROM RIVER BOTTOM
			5.0	10.6	SILT ,STIFF TO HARD (TILL)	
			10.6	15.5	FINE TO VERY FINE SAND	
CNF4	LOT 210, CITY OF NIAGARA FALLS (PREV. STAMFORD TWP., MONTROSE BRIDGE)	172	0.0	5.0	DECAYED VEGETABLE MATTER	
			5.0	6.7	SILTY CLAY	
			6.7	10.4	SILTY CLAY, SOFT	
			10.4	15.7	SILT (TILL)	
			15.7	20.1	BEDROCK	
CNF5	CON. 1, LOT 1 CITY OF NIAGARA FALLS (PREV. CROWLAND TWP., MONTROSE BRIDGE)	174	0.0	3.8	MIXED FILL	
			3.8	8.5	SILTY CLAY WITH SILT LAYERS	
			8.5	9.1	SILTY CLAY	

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Note: Borehole data summarized from Geologic Cross-Section.

8.4.4 ST. LAWRENCE SEAWAY AUTHORITY BOREHOLE LOGS

Borehole locations are shown in Figure 4 (in map pocket).

Borehole elevations are provided to the nearest tenth of a foot in the original data. Elevations have been rounded to the nearest metre in Figure 4.

Borehole logs are photo reduced from copies supplied by the St. Lawrence Seaway Authority in St. Catharines, Ontario and are on file.

SLSA-W1220

PIEZOMETER
TYPE
ELEVATION

TEST BORING NO W 1220
CHAINAGE 2+00 OFFSET 6
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE 571.4 BOTTOM HOLE
BEDROCK GROUNDWATER

ELEV. / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLER TYPE & SIZE	SAMPLE No.	ELEV. / DEPTH
	DARK BROWN WITH ORGANIC INCLUSIONS		SS	1	
	CLAY AND SILT, MOTTLED AND LAYERED, (CONTORTED), WEATHERED — OLIVE TO BROWN AND REDDISH BROWN, OCCASIONAL SILT LENSES			2 3 4 5 6	
561.4 / 10					10
	BROWN WITH NUMEROUS THIN SILT LAYERS AND INCLUSIONS			7 8 9	
				1	20
	INTERBEDDED SILTS, CLAYEY SILTS AND SILTY CLAYS			10	
541.4 / 30					30
	CLAYEY SILT TRACE OF SAND, GREYISH BROWN, OCCASIONAL SUB-ANGULAR GRAVEL TO ½" TILL — ZONE OF LAYERED SILTS (BROWN)			11 12 13	40
521.4 / 50	BOULDER			14	50
				15	60
	CLAYEY SILT, BROWN			16	
	ROCK FRAGMENTS AND SMALL CHUNKS (ANDY SILT (STONY) INCLUSIONS ONLY.			17	70
517.9 / 73.5	BOTTOM OF HOLE 73'				

WATER CONTENT %: 10 20 30 40 50 60
NATURAL WET DENSITY P.C.F.: 110 120 130 140
SHEAR STRENGTH (P.S.F.): TYPE UNCONFINED / QUICK TRIAXIAL / VANE; UNDISTURBED ● ▲; REMOULDED ○ △; STRAIN % ε: 0 5 10; 1000 2000 3000 4000
STANDARD PENETRATION TEST BLOWS/FT: 20 40 60 80 100
PARTICLE SIZE %: 20 40 60 80
WATER DROP INTO T.H. IN

REMARKS: KEWAUNEE CENTRAL [illegible]
CHAINAGE RE KEWAUNEE CENTRAL

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY				
PREPARED	WELLAND CHANNEL RELOCATION				
DRAWN [illegible]	GEOTECHNICAL PROFILES				
CHECKED J.K					
EXAMINED GJC	RECOMMENDED CK	APPROVED	DATE JUNE 6, 1961	BORING NO W 1220	

Observation Well 2010

TEST BORING NO W1169 & W1169A

PIEZOMETER
TYPE
ELEVATION

CHAINAGE OFFSET
CO-ORDINATES: N: E:

ELEVATION
GROUND SURFACE 583.2 BOTTOM HOLE 447.2
BEDROCK 457.6 GROUNDWATER

ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	SAMPLER TYPE & SIZE	SAMPLE No.	ELEV. DEPTH
583.2 0	OLIVE TO REDDISH BROWN; THIN SILT LAYERS		D-3	1	10
	SILTY CLAY; (CH, CI, CL) REDDISH BROWN, LAYERING BROWN & GREY, WEATHERED		CO	2	
573.2			CO	3	20
20	GREY WITH REDDISH BROWN LAYERING AND MOTTLING; WITH SILT ZONES TO 3"		CO	4	
			CO	5	30
	CLAYEY SILT, TRACE OF SAND; BROWN OCCASIONAL PARTICLES SUB-ROUNDED GRAVEL TO ¾" TILL (CL)		D-3	6	
543.2			D-3	7	40
40	SILTY CLAY, BROWN, WITH REDDISH BROWN OR GREY LAYERING OR MOTTLING (CI, CL) WITH FEW SILT INCLUSIONS		D-3	8	
	WITH NUMEROUS CLAYEY SILT ZONES AND INCLUSIONS.		D-3	9	50
523.2			CO	10	
60	CLAYEY SILT, TRACE OF SAND; BROWN, PARTICLES SUB-ANGULAR GRAVEL TO 1" TILL (ML-CL)		CW	11	60
	BOULDERS		LO	12	70
					80
	SAND AND BOULDERS				90
453.2 130					100
					110
457.6 125.7	TOP OF BEDROCK 125.7				120
	BOTTOM OF HOLE 130.0				130
					140

WATER CONTENT % — 10 20 30 40 50 60

NATURAL WET DENSITY P.C.F. — 110 120 130 140

SHEAR STRENGTH (P.S.F.) — TYPE: UNCONFINED, QUICK TRIAXIAL, VANE; UNDISTURBED ● ▲; REMOULDED ⊗ △; STRAIN 15 0 5 10; 1000 2000 3000 4000

STANDARD PENETRATION TEST BLOWS/FT — 20 40 60 80 100

PARTICLE SIZE % — 20 40 60 80

WATER DROP INS/7 MIN.

REMARKS

LIMITS ON SAMPLES NOS. 2, 3, 4, 5, 6 - DONE ON CLAYEY SILT PORTIONS.

ALL REPRESENTATIVE OF CONTACTS IN HOLE.

REMARKS: RE OBSERVATION WELL No 13
LOCATION SOUTH SIDE OF BIGGAR RD.
200' E OF YOUNG RD.

TESTED	THE ST. LAWRENCE SEAWAY AUTHORITY			
PREPARED	WELLAND CHANNEL RELOCATION			
DRAWN M.R.A.	GEOTECHNICAL PROFILES			
CHECKED J.K.	RECOMMENDED	APPROVED	DATE DEC. 23/68	BORING NO W1169 W1169A
EXAMINED C.S.L.				

8.5 SUPPORTING CALCULATIONS AND METHODS

In 1856, the French hydraulics engineer Henry Darcy reported that flow through a porous medium is proportional to the head loss and inversely proportional to the distance travelled. The formulation of these relationships is called Darcy's Law and may be written as; specific discharge (v) = hydraulic conductivity (K) x gradient (i). The specific discharge is the total discharge per unit area of the porous medium and does not indicate the velocity of the water 'particles'. The velocity of the water (average linear velocity, ($\bar{v}$) may be obtained by dividing the specific discharge (v) by the effective porostiy (n) of the porous medium. Because effective porosity is always less than 1, the average linear velocity ($\bar{v}$) is always greater than the specific discharge (v).

Average Linear Velocity ($\bar{v}$) =

$$\frac{\text{Hydraulic Conductivity (K) x gradient (i)}}{\text{effective porosity (n)}}$$

Once the above parameters are known for a porous medium, an average linear velocity may be calculated. The following example utilizes values typical of lateral flow in the fractured zone.

Lateral Ground Water Flow

- hydraulic conductivity (K) 1×10^{-8} m/s
- lateral gradient (i) 0.003
- effective fracture porosity (n) 0.0001

$$\bar{v} = \frac{Ki}{n} = \frac{1 \times 10^{-8} \times 0.003}{0.0001} = 3 \times 10^{-7} \text{ m/s or} \sim 9.5 \text{ m/year}$$

Vertical Ground Water Flow

The application of Darcy's Law to ground water flow through layered porous media when the layers have differing thicknesses and hydraulic properties is discussed in Freeze and Cherry (1979) and is summarized below with regard to the area under study. The layered porous media of interest are the confining layer sub-units which usually include the fractured zone, the unfractured zone and the lower till. Estimating the rates of ground water flow in each of these layers involves (1) the calculation of a single equivalent hydraulic conductivity for the three layers, (2) calculation of the specific discharge through the layers, and (3) the calculation of average linear velocities in each of the layers.

The calculation of an equivalent hydraulic conductvity (Ke) for the three layer situation is:

$$Ke = \frac{d(FCL + CL + LT)}{\frac{dFCL}{KFCL} + \frac{dCL}{KCL} + \frac{dLT}{KLT}}$$

where K and d are the hydraulic conductivity and thickness respectively and the subscripts are 'e' (equivalent), 'FCL' (fractured confining layer), 'Cl' (confining layer) and 'LT' (lower till).

The calcualtion of specific discharge (v) uses the equivalent hydraulic conductivity (Ke) and the overall vertical gradient (i) across the layers in Darcy's Law.

$$v = Ki$$

And finally, the average linear ground water velocity ($\bar{v}$) in each layer is obtained by dividing the specific discharge (v) by the effective porosity (n) for each of the layers involved.

The following example uses numbers similar to those in the report (values relate to the layers identified above; thicknesses are in m and hydraulic conductivities are in m/s).

$$Ke = \frac{17.6}{\frac{5.0}{1x10^{-8}} + \frac{9.3}{3x10^{-10}} + \frac{3.3}{1x10^{-8}}} = \frac{17.6}{3.2x10^{-10}} = 5.5x10^{-10} \text{ m/s}$$

where the vertical gradient (i) is 0.25:

$$v = Kei = 5.5x10^{-10} \times 0.25 = 1.4x10^{-10} \text{ m/s}$$

The average linear velocity ($\bar{v}$) = specific discharge divided by effective porosity for each individual layer.

For the fractured confining layer, effective porosity (n) = 0.0001 and the average (vertical) linear velocity ($\bar{v}$) =

$1.4x10^{-10}/0.0001 = 1.4x10^{-6}$ m/s or $\sim$ 44 m/year

For the unfractured confining layer, no effective porosity value is available and consequently a total porosity value of 0.5 is used to calculate an average linear velocity (v) =

$1.4x10^{-10}/0.5 = 2.8x10^{-10}$ m/s
or $\sim 8.8x10^{-3}$ m/year.

For the lower till, no effective porosity value is available and consequently a total porosity value of 0.3 is used to calculate an average linear velocity =

$1.4 \times 10^{-10}/0.3 = 4.6x10^{-10}$ m/s
or $\sim 1.5x10^{-2}$ m/year.

(These are approximate values and are usually rounded to one significant figure in the text).

The major assumptions for their calculations are:

(1) flow is steady state,
(2) flow is in a direction perpendicular to the layering,
(3) layers are homogeneous and isotropic,
(4) flow is governed by Darcy's Law. A more complete and theoretical discussion is given in Freeze and Cherry (1979).

For a more detailed discussion of ground water flow rates through the confining layer based on advection and diffusion calculations, the reader is referred to Appendix A of the report entitled "Site Selection Process, Phase 4A; Selection of Preferred Site(s), Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

8.6 GLOSSARY OF SELECTED TERMS

8.6 GLOSSARY OF SELECTED TERMS

Sources are provided at the rear of this section and are referenced by the bracketed number following each definition.

Some definitions are altered slightly to reflect useage in this report and may not reflect the wide range of meanings provided in the source.

8.6 GLOSSARY OF SELECTED TERMS

Alluvium
Sediment composed of organic material, clay, silt, sand, gravel cobbles, or boulders deposited by postglacial streams. (2)

Aquifer
A body of sediment (or rock) that contains sufficient saturated permeable material to conduct ground water and yield economically significant quantities of ground water to wells and springs.(2)

Bearing Pressure (Allowable)
Means the maximum pressure that may be safely applied to a soil or rock by the foundation unit in design under expected loading and subsurface conditions. (8)

Confining Bed (Layer)
A body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers. (1)

Darcy's Law
For the velocity of percolation of water in saturated soil: Velocity = coefficient of permeability x hydraulic gradient. (4) (hydraulic conductivity is used in place of coefficient of permeability in this report).

Desiccated Crust
The exposure of fine-grained sediments to drying is accompanied by shrinkage and possibly cracking. Precompression of the upper portions of clay layers by drying is frequently observed in many of the profiles encountered in practice. The effects of desiccation are an increase in strength and a decreased water content. (6)

Drawdown
The lowering of the water level in a well as a result of withdrawal. (1)

Drift
A general term applied to all rock material (clay, silt, sand, gravel, boulders) transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier. (1)

Evaporite
A nonclastic sedimentary rock composed primarily of minerals produced from a saline solution as a result of extensive or total evaporation of the solvent. Examples include: gypsum, anhydrite, rock salt, primary dolomite, and various nitrates and borates. (3)

Geometric Mean
The nth root of the product of the values of n positive numbers; the antilogarithm of the mean of the logarithms of individual values. (1)

Geotechnical, Geotechnics
Pertaining to the broad field of geotechnics. The application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust for the solution of engineering problems. (1)

Glacial Lake
A lake fed predominantly by glacial meltwater or a lake in a depression in part closed by glacial ice. Includes lakes not directly adjacent to the glacier and lakes lying against or on a glacier, and fed mainly by waters derived from the melting of a glacier. (2)

Glaciofluvial
Pertaining to streams flowing from glaciers or to the deposits made by the streams. (2)

Glaciolacustrine
Pertaining to or characterized by glacial and lacustrine (lake) conditions. Material deposited in lakes affected by glacier ice, or deposited by meltwater flowing directly from glaciers into a lake. (2)

Ground Water
Subsurface water occurring below the water table (phreatic surface) in the saturated zone in which all pores are filled with water under hydrostatic pressure. This contrasts with subsurface water above the water table, which is referred to as soil moisture. (2)

Grout
A cement slurry of high water content, fluid enough to be poured or injected into spaces and thereby fill or seal them. (1)

Hardness (Water)
A property of water causing formation of an insoluble residue when the water is used with soap, and forming a scale in vessels in which water has been allowed to evaporate. It is primarily due to the presence of ions of calcium and magnesium, but also to ions of other alkali metals, other metals (e.g. iron), and even hydrogen. Hardness of water is generally expressed as parts per million as $CaCO_3$ (40 ppm Ca produces a hardness of 100 ppm as $CaCO_3$); also as milligrams per litre, and is the combination of carbonate hardness and noncarbonate hardness. (1)

Hazardous Waste
Waste that poses a present or potential danger to human beings or other organisms because it is toxic, flammable, radioactive, explosive, or has some other property that produces substantial risk to life. (1) (Use here excludes radioactive waste)

Heave
A predominantly upward movement of a surface, caused by expansion or displacement, as from swelling clay, removal of overburden, seepage pressure, or frost action. (1)

Hydraulic Gradient
In an aquifer, the rate of change of total head per unit of distance of flow at a given point and in a given direction. (1)

Hydraulic Head
The height of the free surface of a body of water above a given subsurface point. (1)

Hydraulic conductivity
The proportionality factor in Darcy's law as applied to the viscous flow of water in soil, that is, the flux of water per unit gradient of hydraulic potential. (3)

Hydrogeology
The science that deals with subsurface waters and with related geologic aspects of surface waters. (1)

Hydrostratigraphic Unit
A term proposed by Maxey (1964, p. 126) for a body of rock having considerable lateral extent and composing "a geologic framework for a reasonably distinct hydrologic system". (1) (used here for soil and rock).

Infiltration
The flow of a fluid into a solid substance through pores or small openings; specifically the movement of water into soil or porous rock. (1)

Lamina
The thinnest recognizable unit layer of original deposition in a sediment or sedimentary rock, differing from other layers in colour, composition, or particle size; specifically such a sedimentary layer less than 1 cm in thickness (commonly 0.05-1.00 mm thick). (1)

Log
A continuous record as a function of depth, usually graphic and plotted to scale on a narrow paper strip, of observations made on the rocks and fluids of the geologic section exposed in a well bore. (1) (used here for soil and rock).

Moraine
Accumulation of glacial material (mainly till) deposited by glaciers. (2)

Particle Size Classification System (9)

Name	Qualifying Term	Approximate Particle Size (mm)
Boulders		>200
Cobbles		60-200
Gravel	(Pebble)	2-60
Sand	Coarse	0.6-2
	Medium	0.2-0.6
	Fine	0.06-0.2
Silt		0.002-0.06
Clay		<0.002

Permeability
The capacity of a porous medium to transmit a liquid or gas subjected to an energy gradient (in the case of water, hydraulic gradient). (2)

Porosity
The ratio of the volume of voids to the total volume of a soil sample. (4). Effective porosity is the amount of interconnected space available for fluid transmission (3).

Quaternary
The youngest period of the two geologic time divisions of the Cenozoic Era. The Quaternary is subdivided into the Pleistocene and Recent (or Holocene) Epochs. It comprises all geologic time and deposits from the end of the Tertiary (approximately 2 million years ago) until and including the present. (2)

Saturated
Said of the condition in which the interstices of a material are filled with a liquid, usually water. It applies whether the liquid is under greater than or less than atmospheric pressure, so long as all connected interstices are full. (1)

Settlement
Downward movement of a structure such as a railway bridge, dam, or building, due to compression or movement of the soil below it. (4)

Shear Strength
The internal resistance offered to shear stress. It is measured by the maximum shear stress, based on original area of cross-section, that can be sustained without failure. (5)

Two extreme conditions may be recognized: drained conditions, under which the changes in stress are applied so slowly with respect to the ability of the soil to drain that no excess pore pressures develop, and undrained conditions, under which the stresses are changed so rapidly with respect to the ability of the soil to drain that no dissipation of pore pressure takes place. (7)

Slug Test
A method of determining in situ hydraulic conductivity in a single piezometer by causing an instantaneous change in the water level by adding or displacing a known volume of water. (10)

Split Spoon Sampler
Sampling spoons for exploratory borings commonly consist of a pipe with an inside diameter of about 35 mm and an outside diameter of about 51 mm. The pipe is split lengthwise. Consequently the sampler is called a split spoon. While the sample is being taken, the two halves of the spoon are held togther at the ends by short pieces of threaded pipe. One piece serves to couple the spoon to the wash pipe. The other, which has been sharpened, serves as the cutting edge while the spoon is driven into the soil. Exact dimensions are designated in ASTM DI586-67. (7)

Static (Water) Level
That water level of a well that is not being affected by withdrawal of ground water. (1)

Stratigraphic Unit
A stratum or body of adjacent strata recognized as a unit in the classification of a rock sequence with respect to any of the many characters, properties, or attributes that rocks may possess. (1)

Surcharge Load
A weight per unit of area of fill great enough to consolidate the soil sufficiently to increase its strength or reduce its compressibility to the required extent within the time available. Compressible soils such as clays, loose silts, and most organic soils may be compacted by surcharging. (7)

Till
An unsorted mixture of clay, silt, sand, pebbles, cobbles and boulders deposited directly by glacier ice. (2)

Water Table
A surface in the saturated zone below ground level along which the hydrostatic pressure is in equilibrium with the atmospheric pressure. (2)

Weathering
The destructive process or group of processes by which earthy and rocky materials on exposure to atmospheric agents at or near the earth's surface are changed in colour, texture, composition, firmness, or form with little or no transport of the loosened or altered material; specifically, the physical desintegration and chemical decomposition of rock that produce an in situ mantle of waste and prepare sediments for transportion. (1)

SOURCES

(1) Glossary of Geology (Second Edition); R.L. Bates and J.A. Jackson; American Geological Institute, Falls Church, Virginia, 1980.

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(6) Fundamentals of Soil Behaviour; J.K. Mitchell; John Wiley and Sons Inc., 1976.

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8.7 DETAILED FIELD METHODS

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8.7.1. INTRODUCTION

Field data for of the Phase 4A hydrogeologic onsite investigations were collected in a standardized fashion and formed part of the basis for geologic, hydrogeologic, and geotechnical comparisons of the eight candidate sites. An outline of the major field activities is shown in Figure 9. The study approach was modified only slightly on a site-by-site basis to accommodate differing circumstances and site conditions. Standard procedures for the drilling and sampling operations, as outlined in the Gartner Lee Associates Ltd. "Drilling and Sampling Protocol" document (GLAL 1984a), were adhered to throughout the drilling program. This protocol document provides examples of field forms used to document field activities and should be referred to for more detailed drilling and sampling procedural descriptions.

8.7.2. DRILL SITE IDENTIFICATION

8.7.2.1 Preliminary data analysis

A preliminary review of existing water well and test hole data was completed to establish a basis for the selection of tentative drill locations. Criteria used included the following:

- the distribution of existing test holes and water wells;
- the continuity of existing data; and
- anomalous or unusual site conditions.

While locations were selected primarily on technical grounds, practical considerations such as site access, potential crop damage, and landownership were also taken into account.

DETAILED FIELD METHODS

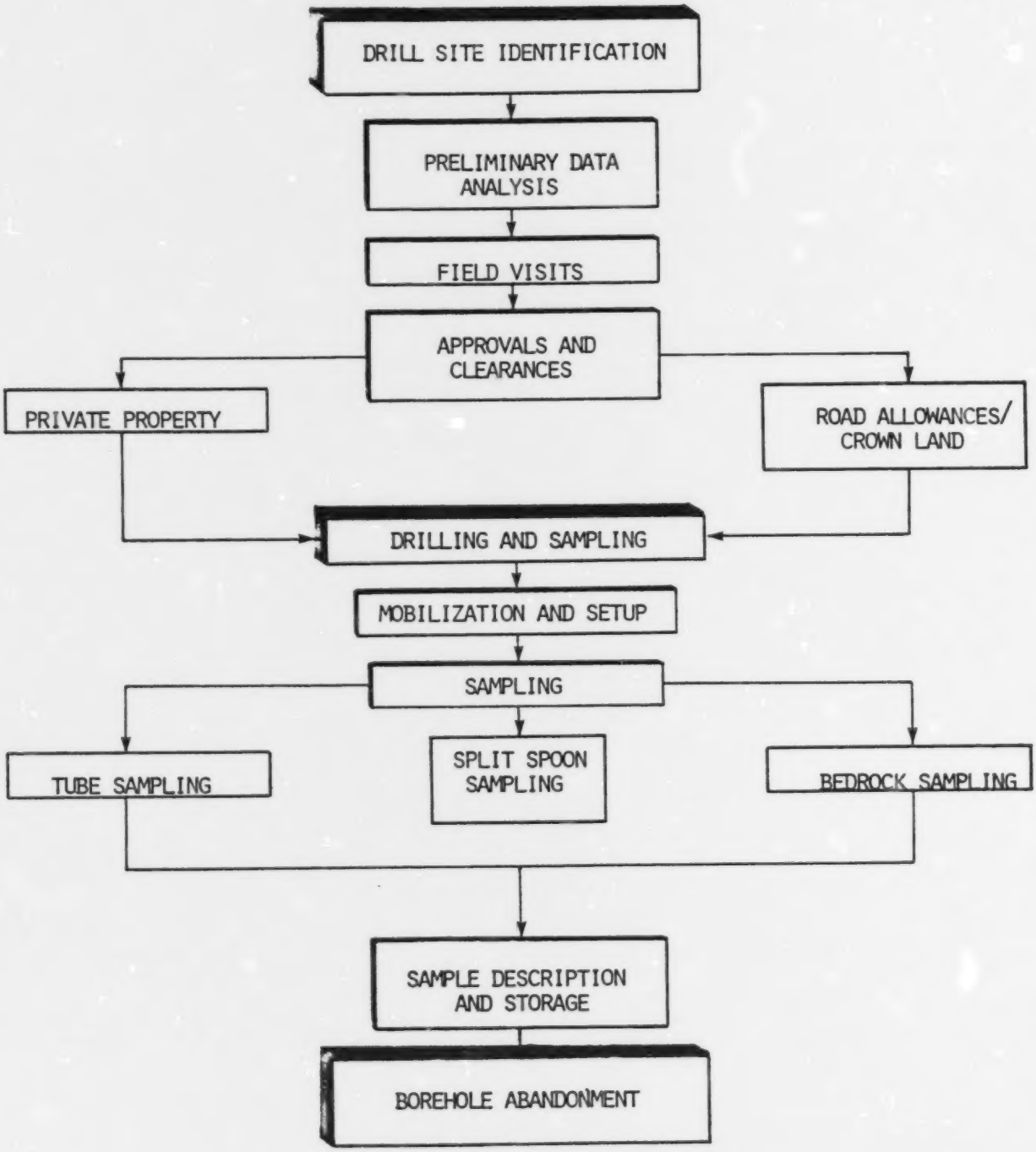


Figure 9

8.7.2.2 Field visits

The concerns of local public interest groups and individuals were also considered in selecting drill locations. Local interest groups were invited to participate during field checking of the drill locations. During these field visits, additional data on water use, local soil conditions, and wells were obtained from local residents. This information was used as a check on some of the field data obtained previously by Ecolgistics Limited during the 1984 "Walk and Talk" survey. The amount of information thus obtained varied from site-to-site and depended largely upon the degree of co-operation given by residents and landowners.

A limited amount of soil probing was completed at Candidate Sites LF-3C, LF-9C, and PI-13N using a 25 mm (1 inch) magnesium hand auger. These investigations were generally limited to a depth of 1 to 2 m. Hand augering was directed toward areas of suspected granular soils or anomalous soil conditions identified by local residents. Soil probing was confined to areas where property access was permitted. Soil descriptions are included under "Field Station Descriptions" in the individual technical site reports.

The tentative drill locations were adjusted during the field visits to avoid difficult or unsafe drilling locations. Each location was marked with a temporary wooden stake. Final adjustments were subsequently made, where necessary, to provide the required safe setbacks from buried and overhead services.

8.7.2.3 Approvals and Clearances

Clearances for both road allowances and adjacent private

or public property were pursued where identified drilling locations were located in the vicinity of local roads. Road allowances were drilled where access to private property was denied.

Landowners and tenants of affected properties were initially contacted by GLAL and verbal approval for test drilling was obtained. Approval was confirmed with a follow up letter from OWMC. For road allowance clearances, the appropriate agencies were contacted and the necessary permit approvals were obtained.

Utilities were contacted and buried service cables and/or pipes were field located by utility personnel and final adjustments of drill locations were completed. Drilling approvals and clearances were completed on a site-by-site basis.

8.7.3 DRILLING AND SAMPLING

8.7.3.1 Drilling equipment and setup

All Terrain Drilling Limited was retained to provide drilling services. The drilling equipment included truck and track mounted CME 75 auger drilling rigs. Two rigs were used simultaneously for most of the drilling program. Each rig was equipped to drill and sample both soils and bedrock. Each rig was staffed with a three man drilling crew and supervised by a GLAL geologist. The drilling program was initiated on August 13, 1984 at Site LF-3C and was completed on November 22, 1984 at Site LF-4N.

The drill rigs were set up in accordance with standard drilling practices and in a manner that allowed the safe

and efficient operation of the equipment. A safety corridor was roped-off around the drill rig to limit access to the rigs. Access to the roped-off area was restricted to individuals with proper safety equipment which included steel-toed boots and a hard hat. A record was kept of all visitors to the drill site as well as persons entering the roped-off area.

Sample documentation and storage facilities were set up at the edge of the roped-off area by GLAL. Soil and rock samples were accessible to the general public for viewing and/or photographing as the samples were being logged by the onsite geologists. Samples were subsequently sealed in tubes or core boxes, labelled, and placed in storage. On several occasions, soil sample tubes were re-opened for examination at the request of local residents.

8.7.3.2 Soil sampling

The drilling program was designed to obtain a continuous column of soil from the ground surface to and including the upper few metres of the underlying bedrock. Soil samples were obtained using hollow stem auger drilling techniques. Hollow stem augers (108 mm (4.25 inch) inside diameter) were used throughout the drilling program.

Split tube sampling. Tube samples measuring approximately 89 mm (3.5 inches) in diameter by 1.52 m (5 ft.) in length were taken continuously from ground level to the bedrock surface. The tube sampler consisted of a split tube with a bevelled sampler tip. The split tube was threaded at both ends and fastened to the drill rods as shown in Figure 10. The sampler as advanced inside the hollow stem augers with

Continuous Soil Sampling With Split Tube Sampler

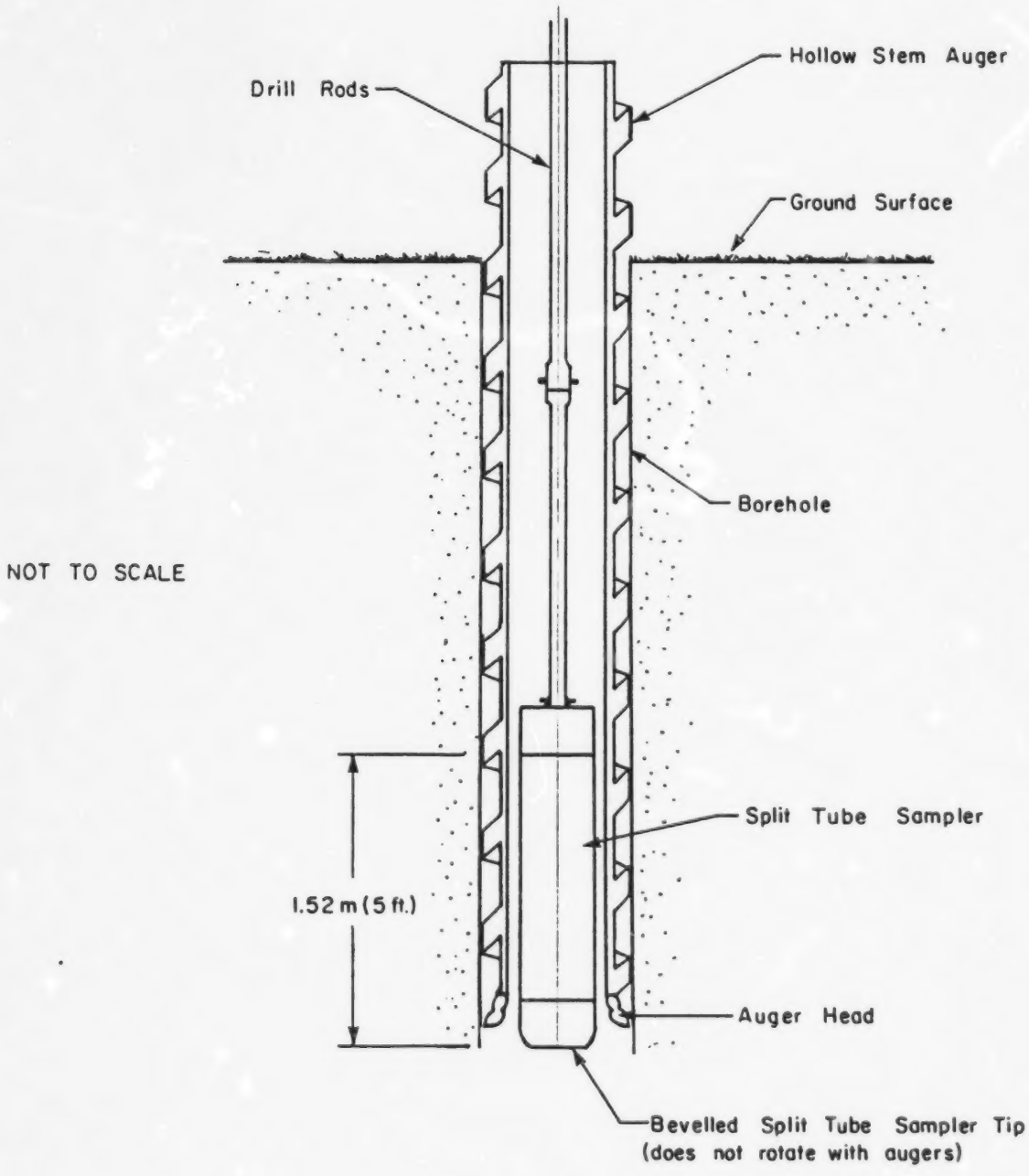


Figure 10

the bevelled tip slightly ahead of the cutting edge of the augers. A split tube sample was obtained by advancing the sampler with the rotating augers. The augers and sampler were advanced at about 1.52 m (5 ft.) intervals or until refusal, and the sampler was then withdrawn from the borehole. The soil sample was removed from the tube and the sampler washed with clean water. Sample recovery for the tube samples was generally between 90 to 100% and was recorded in the field log. Difficult drilling conditions or large cobbles occasionally resulted in lower sample recovery.

Split spoon sampling. Standard split spoon samples were taken at about 1.52 m (5 ft.) intervals throughout the soil sequence overlying bedrock and beginning at about 1.52 m 5 ft.) from the ground surface. Sample intervals are shown schematically in Figure 11.

The split spoon sampler was driven by dropping a 63.5 kg (140 lb.) weight a distance of about 750 mm (30 inches). The sampler was inserted inside the hollow stem augers in a similar fashion to the tube sampler. It was then driven into the soil below the bottom of the augers a distance of about 460 mm (18 inches) or until refusal. The number of blows required to advance the sample for each interval of about 150 mm (6 inches) was recorded in the field log. The split spoon was usually withdrawn when 50 or more blows were required to advance the sampler approximately 150 mm (6 inches) into the subsoil.

Standard split spoon samples were obtained in place of tube samples where difficult drilling conditions were

Soil & Rock Sample Intervals, Phase 4A Drilling Program

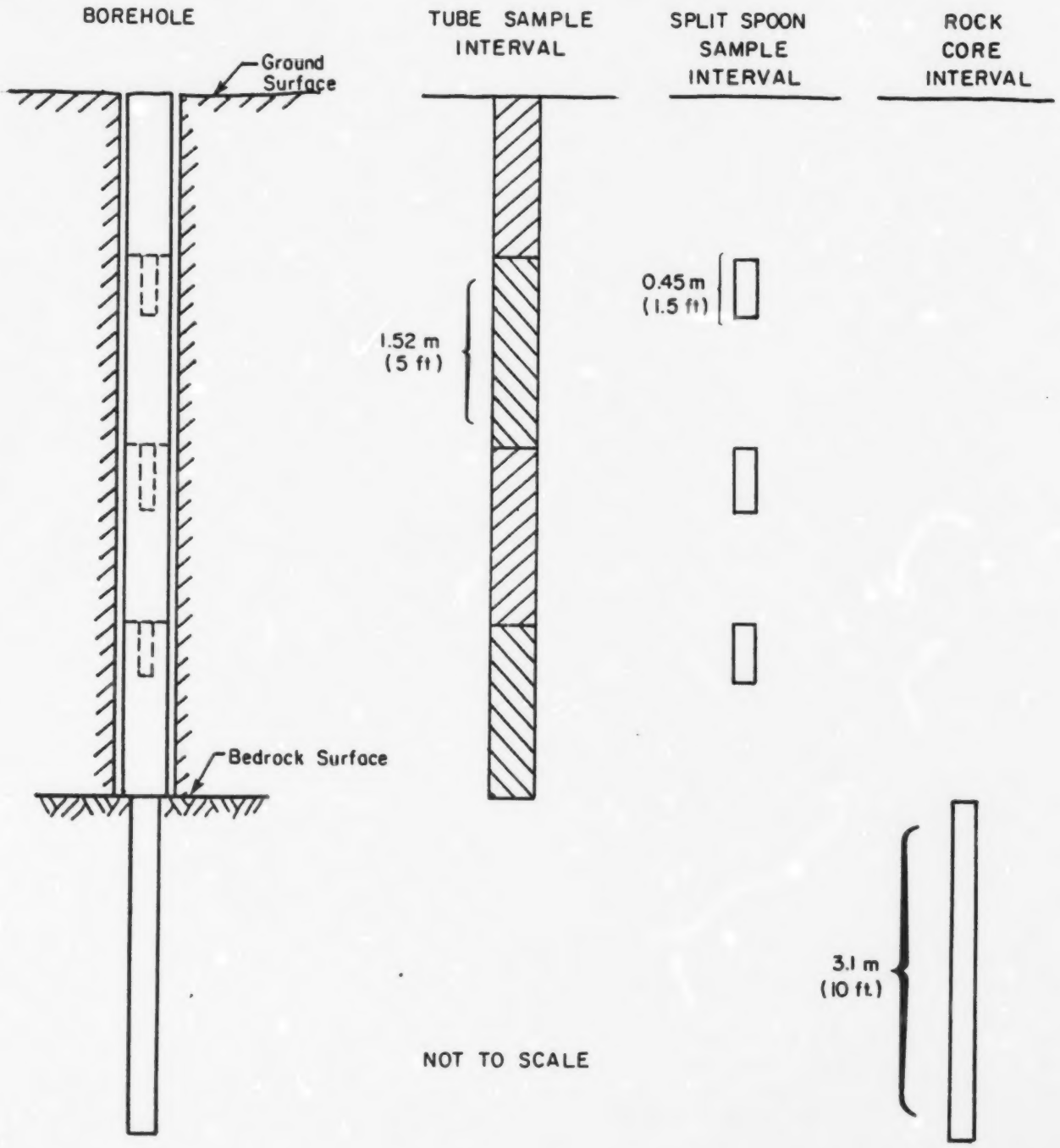


Figure 11

encountered. At Site LF-4N, Borehole 4, granular soils were encountered at a depth of about 30 m (100 ft.) causing refusal of the tube sampler. Standard split spoon samples were taken from a depth of 30 m (100 ft.) at intervals of 0.5 to 3 m (1.6 to 9.8 ft.) to a depth of about 40 m (130 ft.). Difficult soil conditions were also encountered at Site LF-2N, Borehole 1. Numerous rock fragments were encountered below a depth of about 12 m (40 ft.) at this location. Split spoon samples at 0.76 m (2.5 ft.) intervals were taken between depths of about 12 m (40 ft.) to 34 m (110 ft.).

Difficult (sandy and gravelly) soil conditions at Site PI-27E, Borehole 3 prevented tube sampling between depths of about 16 to 30 m (50 to 100 ft.). Similar fine, sandy soils were also encountered in Borehole 4 at this site at depths between approximately 24 to 30 m (80 to 100 ft.). Standard split spoon samples at 1.5 m (5 ft.) intervals were collected over these intervals at these two borehole locations.

Moisture tin samples. A small soil sample of approximately 100 grams was taken from the tip of each split spoon sample for laboratory determination of the soil moisture content. Soil moisture samples were placed in air tight tins immediately after they were taken from the split spoon samples. The moisture tin (sample) numbers were recorded on the field borehole logs. The samples were temporarily stored in the field and shipped in batches to the GLAL office for transfer to a commercial laboratory.

Rotary drilling. Rotary drilling techniques were occas-

ionally used to penetrate difficult soils that could not readily be drilled with conventional hollow stem auger drilling methods. These techniques were also used where granular soils, acting under hydraulic pressures, were forced up inside the hollow stem augers. This condition prevented the split tube and split spoon samplers from passing through the plugged portions of the hollow stem augers. Clean water or a water/bentonite mixture was circulated through a rotating tricone drill bit to clean out the material in the hollow stem augers. Rotary drilling was also used to drill through gravelly or bouldery soils such as those encountered at depth at Site LF-4N, Borehole 4, and at Site LF-2N, Borehole 1.

8.7.3.3 Bedrock sampling

Boreholes were generally completed into bedrock except in a few cases where difficult drilling conditions were encountered and the borehole was terminated before reaching bedrock.

The bedrock contact was often obscured as a result of weathering, particularly in shale. Under conditions of extreme weathering, shale was occasionally retrieved within the split tube and split spoon samplers. For example, a nearly complete 1.5 m core of weathered bedrock was obtained in the split tube sampler in Borehole 5 at Site PI-13N.

Diamond drill coring. Most bedrock samples were obtained using a diamond drill bit and NX size core barrel. Rock core samples generally measured about 53 mm (2.1 inches) in diameter and up to 3 m (10 ft.) in length. The diamond drill bit and core barrel were positioned on the bedrock

surface from inside the hollow stem augers. A rock core was obtained by the cutting action of the rotating drill bit. Clean water was circulated in the borehole to remove cuttings from around the drill bit. The water used in this operation was field checked with a Hach Kit for chlorides and sulphates to ensure compatibility with grouting materials used for borehole abandonment. The amount of water used was recorded on the field logs.

Bedrock coring was terminated when a sufficient length of sample was retrieved to prove-out the bedrock contact. The bedrock core recovered varied in length from about 1.5 m to 3 m (5-10 ft.) between borehole locations.

8.7.3.4 Sample description and storage

Soil and rock samples, taken from the boreholes, were described in detail in the field and photographed. Sample descriptions were recorded on the Field Borehole Log forms. These logs, together with the sample photos, form a permanent record of the sampling procedures.

The tube samples were transferred directly from the sampler into PVC tubular piping which was cut in half. The PVC pipe measures 89 mm (3.5 in.) inside diameter by 1.5 m (5 ft.) long. One 'side' of the sample was scraped clean along its length with a knife or spatula to facilitate sample description. Individuals and local interest groups were allowed to view the samples and make their own field notes of the samples. Soil scrapings were given to those interest groups that requested them or else were discarded. Soil samples were sealed in the PVC tubes by covering the

ends with plastic caps and taping the entire tube along the seams. Sample labels were affixed to each PVC tube.

The samples were stored temporarily in a field van until a sufficient number of samples were obtained for transport to permanent storage facilities in Toronto at the Ontario Geological Survey. Each shipment of samples were itemized on a Sample Packing list. The contents of each shipment were also recorded on a Chain of Custody Record which showed the times and dates of sample transfer as well as the individuals involved in handling the samples.

Split spoon soil samples taken during the project were described in the field and soil moisture (moisture tin) samples taken from the base of the split spoon sampler were submitted to a laboratory for analysis. The moisture tin number was recorded on the Field Borehole Log and on the Sample Packing List. In cases where a split spoon sample was taken in place of the larger split tube samples, they were stored in labelled plastic bags and retained with the other samples. The top of each bedrock core segment was marked on both the core boxes and on the rock core itself with a felt marker.

The soil and rock samples were re-examined by a senior GLAL geologist at the permanent storage area at the Ontario Geological Survey. The field descriptions were combined with the more detailed geologic log prepared by the senior geologist to compile a final borehole log. All soil samples were resealed after examination.

8.7.4 BOREHOLE ABANDONMENT

Boreholes were generally terminated after pentrating the bedrock or when difficult conditions prevented further drilling. An exception to this occurred at Site LF-1E, Borehole 3, where a gas pocket was encountered at a depth of about 17.8 m (58 ft.) in the drift. The borehole was terminated at this depth and sealed as soon as the gas pressure subsided sufficiently to allow grouting.

8.7.4.1 Grouting

On completion of each borehole all sampling equipment and temporary casing were removed from the borehole. Each borehole was then filled to the surface with a cement/ bentonite slurry. This was accomplished by injecting grout through the hollow stem augers as they were slowly withdrawn from the hole as shown in Figure 12. Specifications of the slurry mix, as set out in the Drilling and Sampling Protocol Document (GLAL 1984a) were altered slightly to accommodate site conditions. The actual grout slurry mix is compared on a percent weight basis to the specified grout slurry mix below:

Specified Grout Slurry	Actual Grout Slurry
1.2% Bentonite	2-3% Bentonite
6.0% Hydrated Lime (optional)	
59.6% Cement (Portland Type 10)	40-60% Cement (Portland Type 10)
33.2% Water	37-58% Water

The increased amount of bentonite provides a more effective seal in water bearing formations. The bentonite also acts as a 'plasticizing' agent and eliminated the need

Grouting Of Borehole

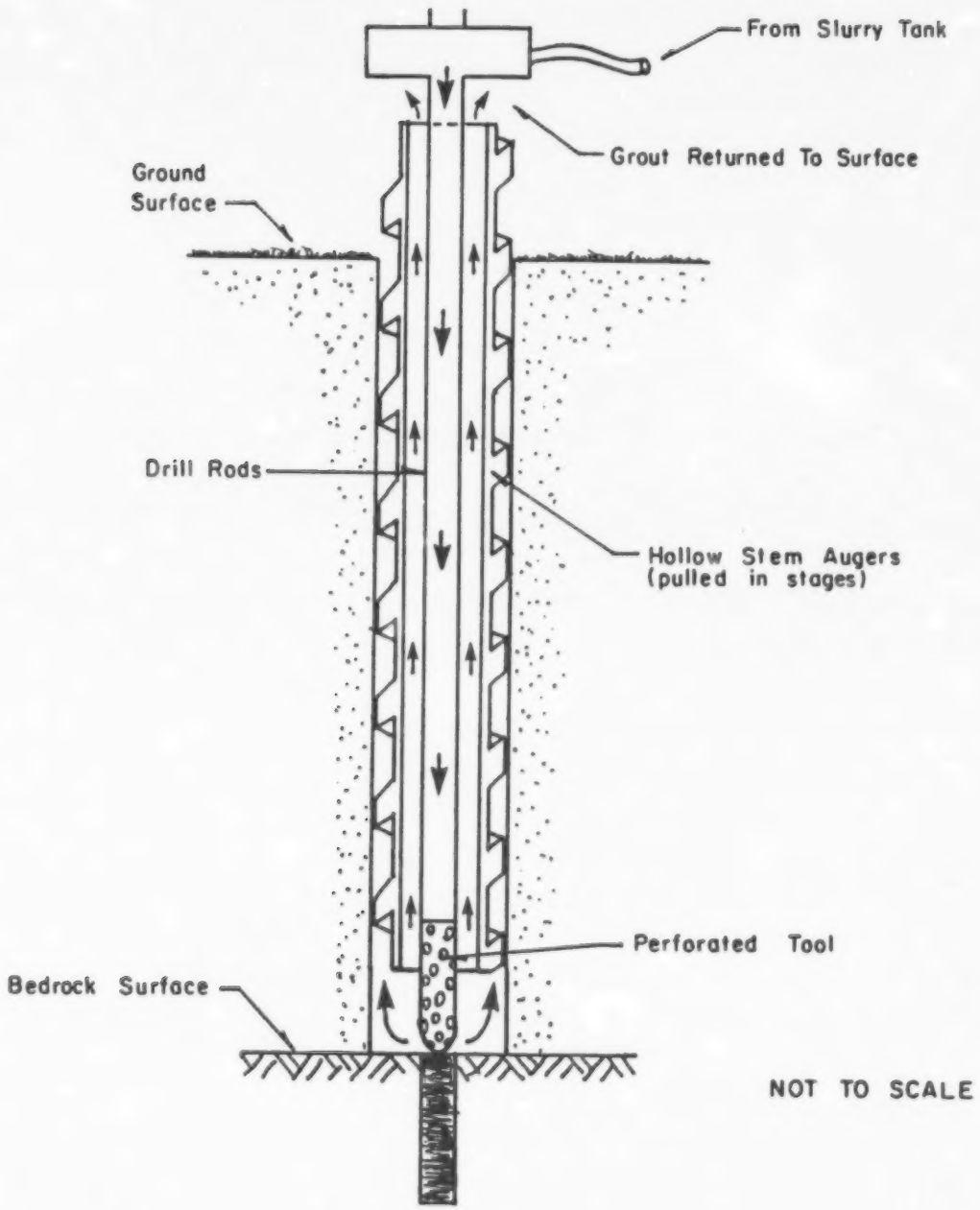


Figure 12

to add hydrated lime to the grout slurry mix. A cement mix containing slightly less than the amount of cement specified in the protocol was found to be adequate. A small sample of grout slurry was taken from each hole to confirm the setting characteristics of the mix.

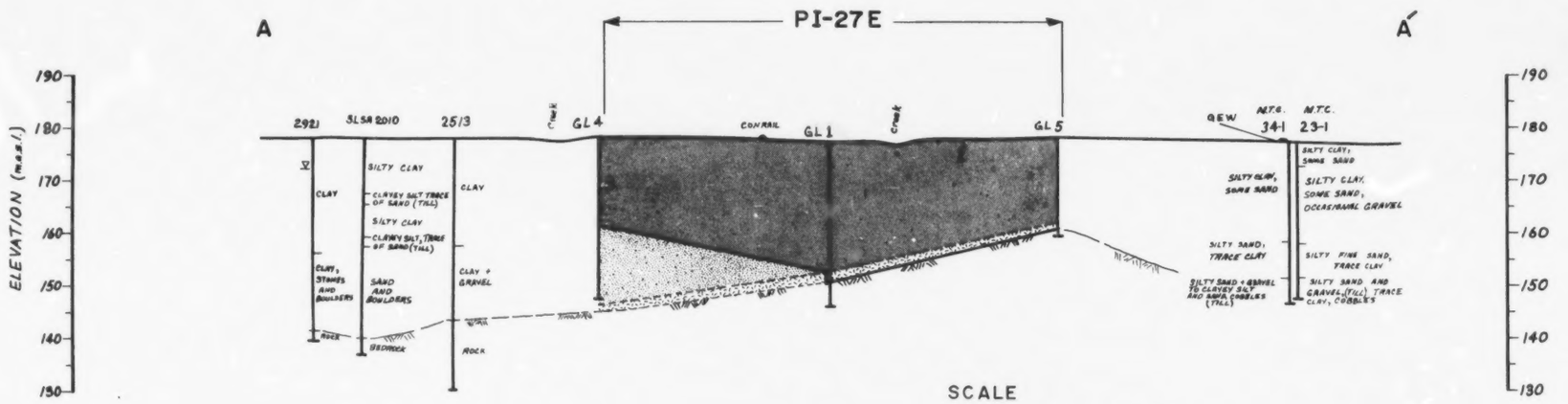
The water used in the grout slurry was obtained locally and was tested wth a Hach Kit for sulphate and chloride content. Details of each grout mix were recorded on the Borehole Plugging Plan/Record for each borehole.

The grout was allowed to set overnight and generally settled to within 1 to 3 m (3-10 ft.) of ground surface. The hole was subsequently backfilled to grade with soil to avoid interference with surface activities such as ploughing or maintenance along road allowances. All boreholes from this drilling program were successfully grouted.

8.7.4.2 Site cleanup

Efforts were made to restore each drill location to predrilling conditions. The ground was levelled to grade and holes or ruts made by drilling equipment were filled with soil and in some cases resodded. While attempts were made to minimize damage, this was not always possible and compensation was provided in some cases. Photographs were taken of each drill location both before and after the drilling operations and after site cleanup.

West — Looking North — East



(Geologic conditions between boreholes may vary from interpretations shown)

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

Site PI-27E
CROSS-SECTION A-A'
Figure 5

LEGEND

- GL 3 — Gartner Lee Associates Limited (GLAL) Borehole
- 417 — Ministry of Environment Water Well Record Number
- SLSA — St Lawrence Seaway Authority Borehole
- MTC 23-1 — Ministry of Transportation and Communications Borehole
- ▽ — Static Water Level in Well at Time of Well Construction
- m.a.s.l. — Metres above sea level

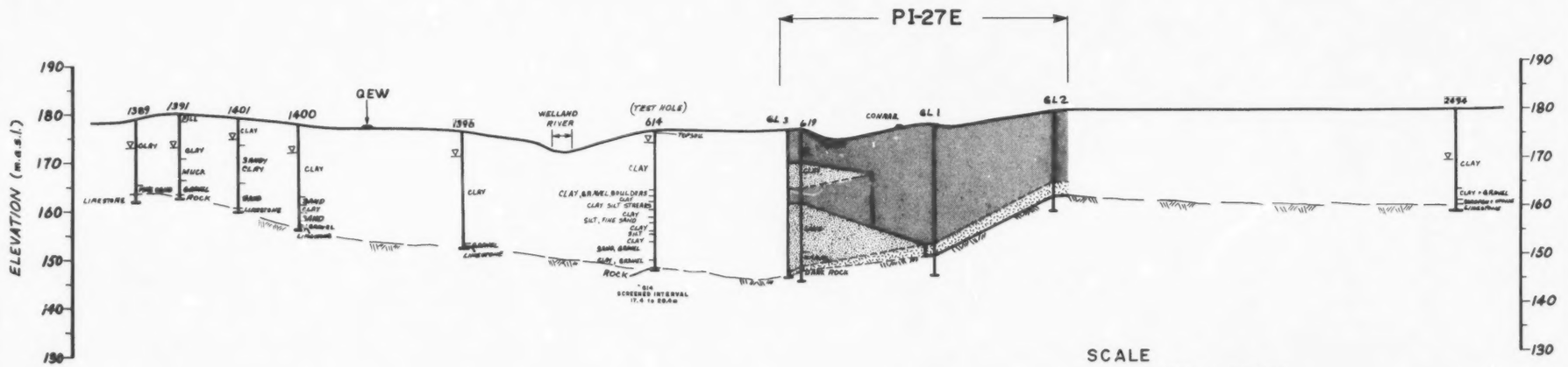
INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- CLAYEY SILT AND SILTY CLAY (Upper Glaciolacustrine, Halton Till, and Lower Glaciolacustrine)
- SAND
- SILT TILL (Lower Till)
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

NOTES:
- Consult Water Well Record Summary and Borehole Logs in Sections 8.1 and 8.4 for detailed descriptions.
- Elevations are approximate
- Cross-Section Located in Figure 4
- To accompany Phase 4A Technical Appendix (Geologic Hydrogeologic and Geotechnical Considerations)

OWMC Ontario Waste Management Corporation
Consultant: Gartner Lee Associates Limited

North — Looking East — South



(Geologic conditions between boreholes may vary from interpretations shown)

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

Site PI-27 E
CROSS-SECTION B-B'
Figure 6

LEGEND

- GL 3 — Gartner Lee Associates Limited (GLAL) Borehole
- 417 — Ministry of Environment Water Well Record Number
- ▽ — Static Water Level in Well at Time of Well Construction
- m.a.s.l. — Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- CLAYEY SILT AND SILTY CLAY (Upper Glaciolacustrine, Halton Till, and Lower Glaciolacustrine)
- SAND
- SILT TILL (Lower Till)
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

NOTES:
- Consult Water Well Record Summary and Borehole Logs in Sections 8.1 and 8.4 for detailed descriptions.
- Elevations are approximate
- Cross-Section Located in Figure 4
- To accompany Phase 4A Technical Appendix (Geologic Hydrogeologic and Geotechnical Considerations)

OWMC Ontario Waste Management Corporation
Consultant: Gartner Lee Associates Limited

MCLEOD ROAD
BROWN ROAD
CHIPPAWA CREEK ROAD
REG. RD. 63
GRASSY BROOK ROAD
GRASSY BROOK
THOMPSONS CREEK
GARNER ROAD
ALAR ROAD
MONTROSE
FRASER
NIAGARA FALLS
OAKWOOD DRIVE
CHIPPAWA PARK WAY
LYONS CREEK ROAD
ROAD 70
ROAD 63
Lot 168
Lot 177
Lot 8 BF
Lot RF
City of Niagara Falls
Chippawa Power Canal
Wetland
Grassy Brook

Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

- GL — GARTNER LEE ASSOCIATES LIMITED BOREHOLE
- MTC — MINISTRY OF TRANSPORTATION AND COMMUNICATIONS BOREHOLE
- SLSA — ST. LAWRENCE SEAWAY AUTHORITY BOREHOLE
- CNF — CITY OF NIAGARA FALLS BOREHOLE
- 2673 — WATER WELL WITH MINISTRY OF ENVIRONMENT NUMBER
- 24.1 — THICKNESS OF CONFINING LAYER (IN METRES)

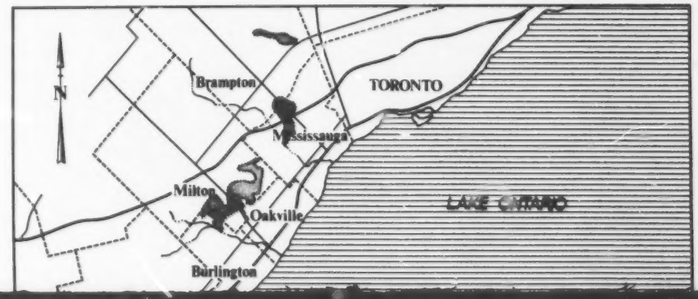
Phase 3B Acquisition Boundary

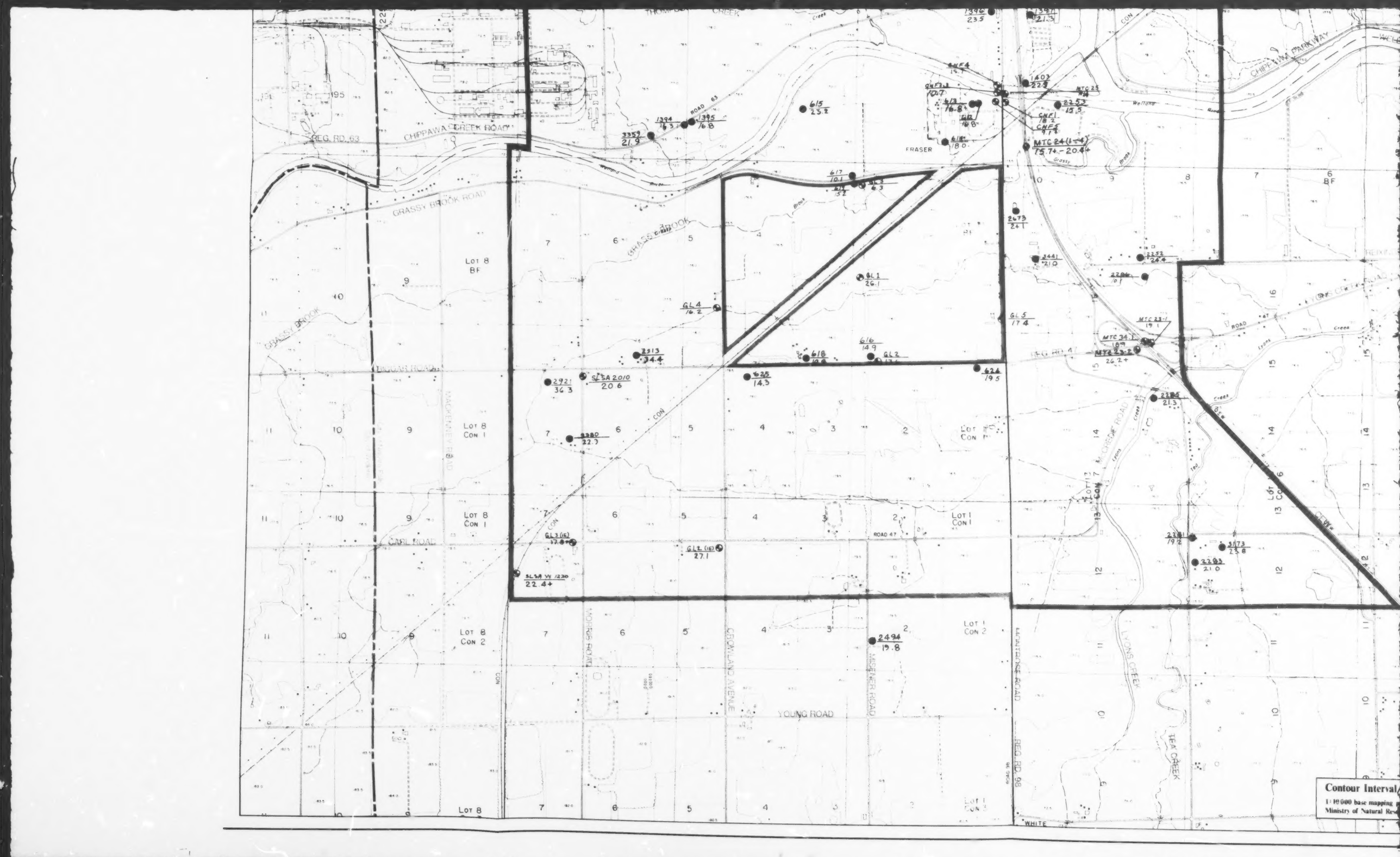
Site Vicinity Study Area Boundary

Key Map:

PI-27 East

Part of Lots 1, 2, 3, and 4; Broken Front Concession Welland River; City of Niagara Falls; formerly in the Township of Crowland



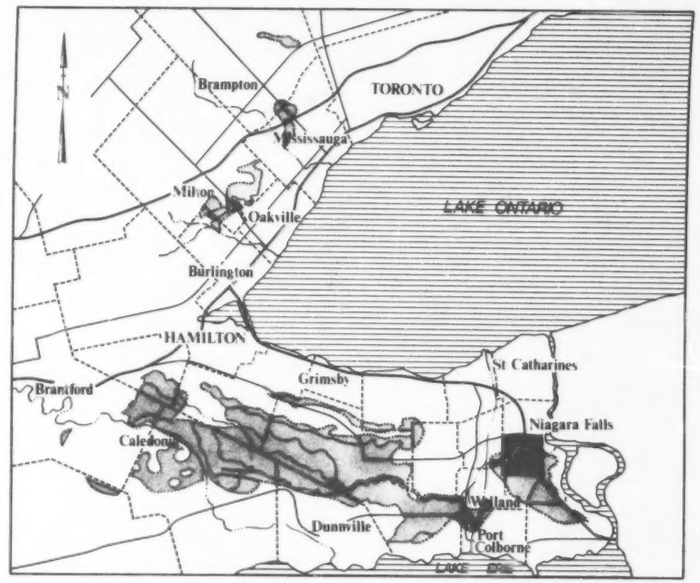

REG. RD. 63
CHIPPAWA CREEK ROAD
GRASSY BROOK ROAD
GRASSY BROOK
LINCOLN ROAD
MACKENZIE ROAD
CASEL ROAD
CON
ROAD 63
ROAD 47
FRASER
CHIPPEWA PARKWAY
MORRIS ROAD
CROWLAND AVENUE
YOUNG ROAD
MESSNER ROAD
MAINTENANCE ROAD
REG. RD. 98
LYONS CREEK
TEA CREEK
WHITE
LOT 8 BF
LOT 8 CON 1
LOT 8 CON 2
LOT 1 CON 1
LOT 1 CON 2
Contour Interval
1:10000 base mapping
Ministry of Natural Re

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map:

PI-27 East

Part of Lots 1, 2, 3, and 4; Broken Front Concession Welland River; City of Niagara Falls; formerly in the Township of Crowland



1000 feet 0 1000
500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Confining Layer Thickness

September 1985

FIGURE 7

Contour Interval in Metres

1:10 000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

MCLEOD ROAD
BROWN ROAD
GARNER ROAD
KALAR ROAD
DORCHESTER ROAD
OAKWOOD DRIVE
CHIPPAWA PARKWAY
CHIPPAWA CREEK ROAD
REG. RD. 63
GRASSY BROOK ROAD
REG. RD. 47
LYONS CREEK ROAD
THOMPSONS CREEK
MONTROSE
FRASER
NIAGARA FALLS
LOT 168
LOT 8 BF
LOT BF
CON

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

- DRILLED WELL COMPLETED IN OVERBURDEN, BEDROCK
- DUG OR BORED WELL
- UNKNOWN WELL TYPE
- FLOWING CONDITIONS
- UNUSED, ABANDONED WELL
- DUGOUT OR POND
- CISTERN
- ADDITIONAL FIELD INFORMATION

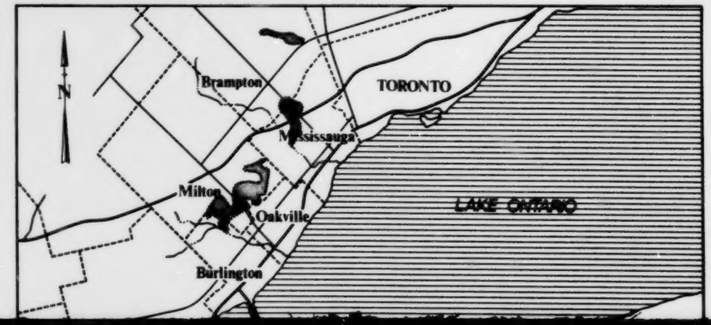
NOTES: Details for wells with Ministry of Environment numbers (3 and 4 digits) are provided in the Summary of Water Well Data (Table 4, Section 8.1); Other numbers accompany wells, cisterns, dugouts or ponds, and locations where 'additional field information' was gathered. Details for these are provided in the Summary of Site Interview Data (Table 6, Section 8.3)

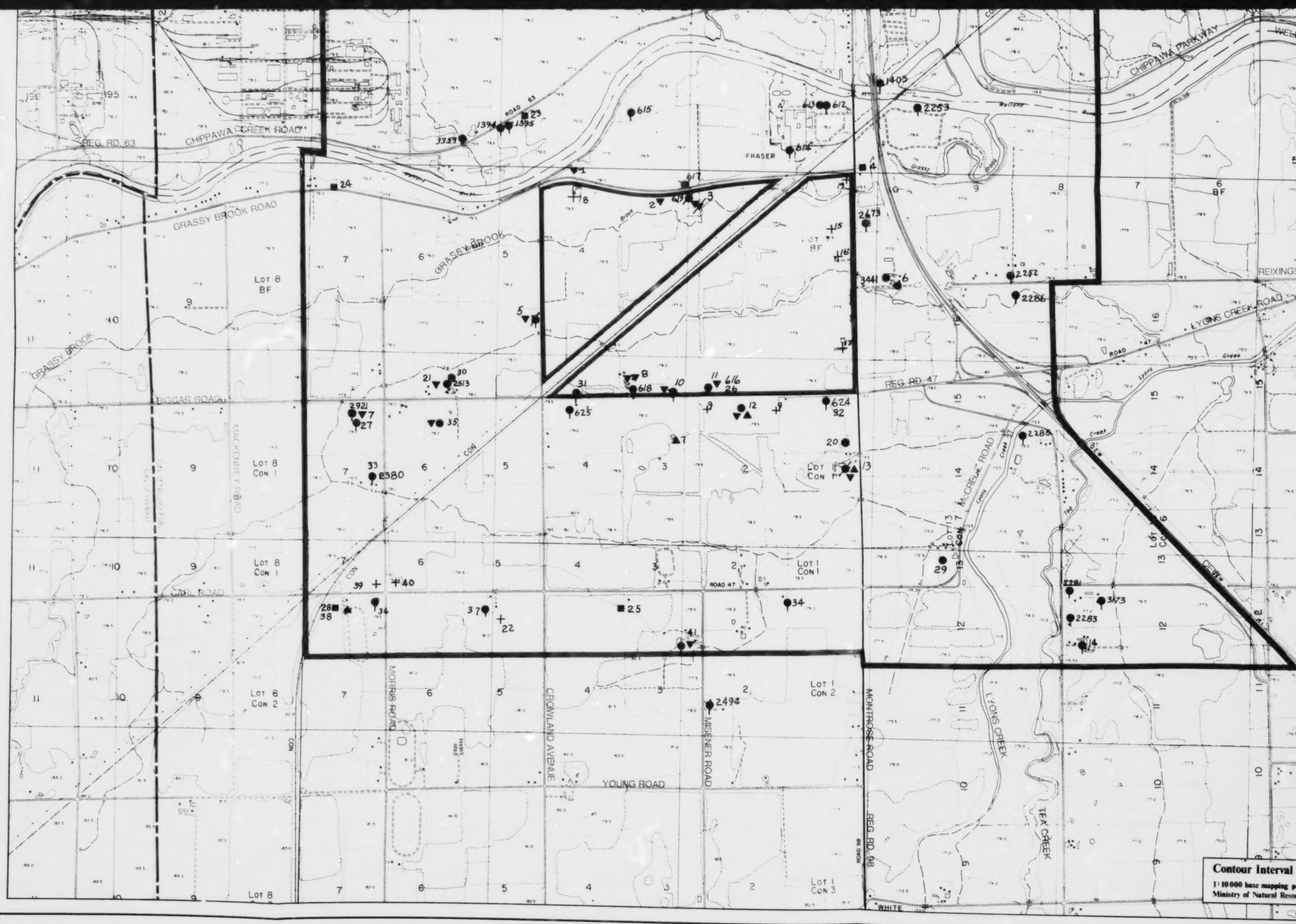
Phase 3B Acquisition Boundary **Site Vicinity Study Area Boundar**

Key Map:

PI-27 East

Part of Lots 1, 2, 3, and 4; Broken Front Concession Welland River; City of Niagara Falls; formerly in the Township of Crowland

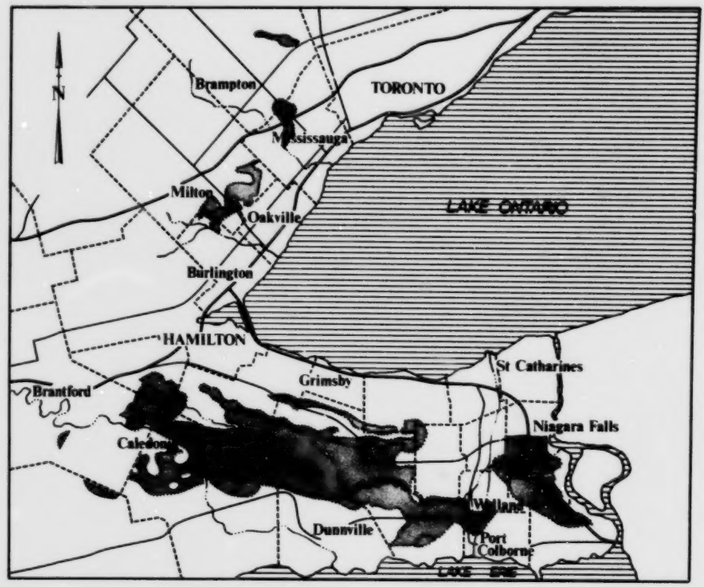



CHIPPAWA CREEK ROAD
REG. RD. 63
GRASSY BROOK ROAD
BIGGAR ROAD
MACKENNEY ROAD
GRASSY BROOK
CON
LOT 8 BF
LOT 8 CON 1
LOT 8 CON 2
LOT 1 CON 1
LOT 1 CON 2
LOT 1 CON 3
MORRIS ROAD
CROWLAND AVENUE
MISENER ROAD
YOUNG ROAD
FRASER
CHIPPAWA PARKWAY
REIXINGER
LYONS CREEK ROAD
REG RD 47
McCREIGHT ROAD
MONTROSE ROAD
REG RD 98
LYONS CREEK
TEA CREEK
WHITE
Contour Interval
1:10000 base mapping p
Ministry of Natural Reso

Phase 3B Acquisition Boundary — Site Vicinity Study Area Bound

Key Map: **PI-27 East**

Part of Lots 1, 2, 3, and 4; Broken Front Concession Welland River; City of Niagara Falls; formerly in the Township of Crowland



1000 feet 0 1000
500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Ground Water Use

September 1985

FIGURE 8

Contour Interval in Metres

1:10 000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

Number/
Numéro

7

SITE SELECTION PROCESS - PHASE 4A

TECHNICAL APPENDIX PI-1N

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS

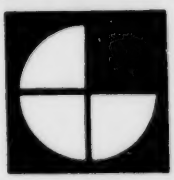
A REPORT PREPARED FOR
THE ONTARIO WASTE MANAGEMENT CORPORATION
BY
GARTNER LEE ASSOCIATES LIMITED

THIS REPORT IS ONE OF EIGHT TECHNICAL APPENDICES DESCRIBING GEOLOGIC, HYDROGEOLOGIC AND GEOTECHNICAL CONSIDERATIONS OF THE CANDIDATE SITES. IT SUPPORTS THE COMPARATIVE EVALUATION STUDY WHICH IS ENTITLED "SITE SELECTION PROCESS; PHASE 4A, SELECTION OF PREFERRED SITE(S); GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS".

SEPTEMBER, 1985.

PROJECT 85-S18.3

Gartner Lee
Associates Limited



Gartner Lee Associates Limited

Consulting Engineering
Geologists
Biologists and
Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-477-8400
Telex-06-986278

September 11, 1985.

Dr. B.D. Mitchell,
Director of Corporate Planning and Development,
Ontario Waste Management Corporation,
2 Bloor Street West,
11th Floor,
Toronto, Ontario
M4W 3E2.

Attention: Mr. J.G. Micak,
Manager,
Environmental Projects.

Dear Dr. Mitchell:

Re: Site Selection Process - Phase 4A
Technical Appendix PI-1N - Geologic, Hydrogeologic and Geotechnical Considerations

Enclosed is our final report on the Geologic, Hydrogeologic, and Geotechnical Considerations at Candidate Site PI-1N. Similar reports prepared for each of the other candidate sites will form the basis for site comparisons.

Thank you for allowing our company to be of service.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

E.G. Anderson, P.Eng.,
Project Director.

KJG:jcm
Enclosures.

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STUDY TEAM

This report was prepared under the overall direction of Grant Anderson, P.Eng., Project Director and Gunther Funk, Project Manager.

Major contributing authors were:

Hydrogeology	Kenneth Goff
Geology	Andrew Cooper
Geotechnics	Douglas Jagger, P.Eng.
Field Co-ordinator	Norbert Woerns

1.0 INTRODUCTION

1.1 BACKGROUND

The Ontario Waste Management Corporation (OWMC) site selection process to locate facilities for treating hazardous wastes and disposing of the treated waste residues has been a phased process which began in 1981. Initial studies identified 261 hydrogeologic areas throughout southern Ontario which were grouped into six zones. Within the Golden Horseshoe, zone 1 and 2 lands were considered most favourable for facility siting. Twenty candidate areas were identified within the Zone 1 and 2 lands in the Golden Horseshoe in 1983. A total of 152 sites were identified in these twenty candidate areas in 1984 and this number was subsequently reduced in stages to sixteen potential sites and finally to eight candidate sites through the application of various constraints, screening processes, and ranking systems based on multidisciplinary factors. A more complete discussion of the site selection process is provided in the comparative evaluation study (GLAL 1985).

The present stage of study is the comparative assessment of siting options for the eight candidate sites. This Gartner Lee Associates Limited (GLAL) report documents and interprets available geologic, hydrogeologic, and geotechnical information for Site PI-1N and serves as the data source for input to the Phase 4A comparison study. The candidacy of this site is based on the potential development of a physical-chemical treatment and/or incinerator facility.

The Phase 3B preliminary assessment of this site was based primarily on existing data (GLAL 1984b). Phase 4A investigations described in this report add significantly to the geologic, hydrogeologic and geotechnical data base.

1.2 OBJECTIVES AND SCOPE

The objectives of this study are to provide data for Site PI-1N to accommodate comparisons with the other siting options. These objectives have been met through additional investigations. The existing data base has been upgraded where possible and five boreholes have been drilled on the site. Each of the boreholes has been continuously sampled to provide detailed geologic logs and soil samples. Boreholes were not instrumented and were grouted on completion.

1.3 LOCATION

Site PI-1N is located in the Regional Municipality of Halton. It is shown together with the other candidate sites in Figure 1. Site PI-1N is presented in greater detail in the figures in the map pockets at the rear of the report.

The site under consideration in this Technical Appendix covers approximately 378 hectares (ha) and includes Lots 3, 4, and 5, Concession 2, and Lots 3, 4, and 5, Concession 1, in the Town of Milton (formerly in the Township of Trafalgar). It is bounded on the northeast by Highway 25, on the northwest by Britannia Road (Regional Road 6) and on the southwest by the Canadian National Railway. The site is roughly centered in a study area of about 2400 ha. It is located within the corporate limits of the Town of Milton and is about 7 km south of Highway 401.

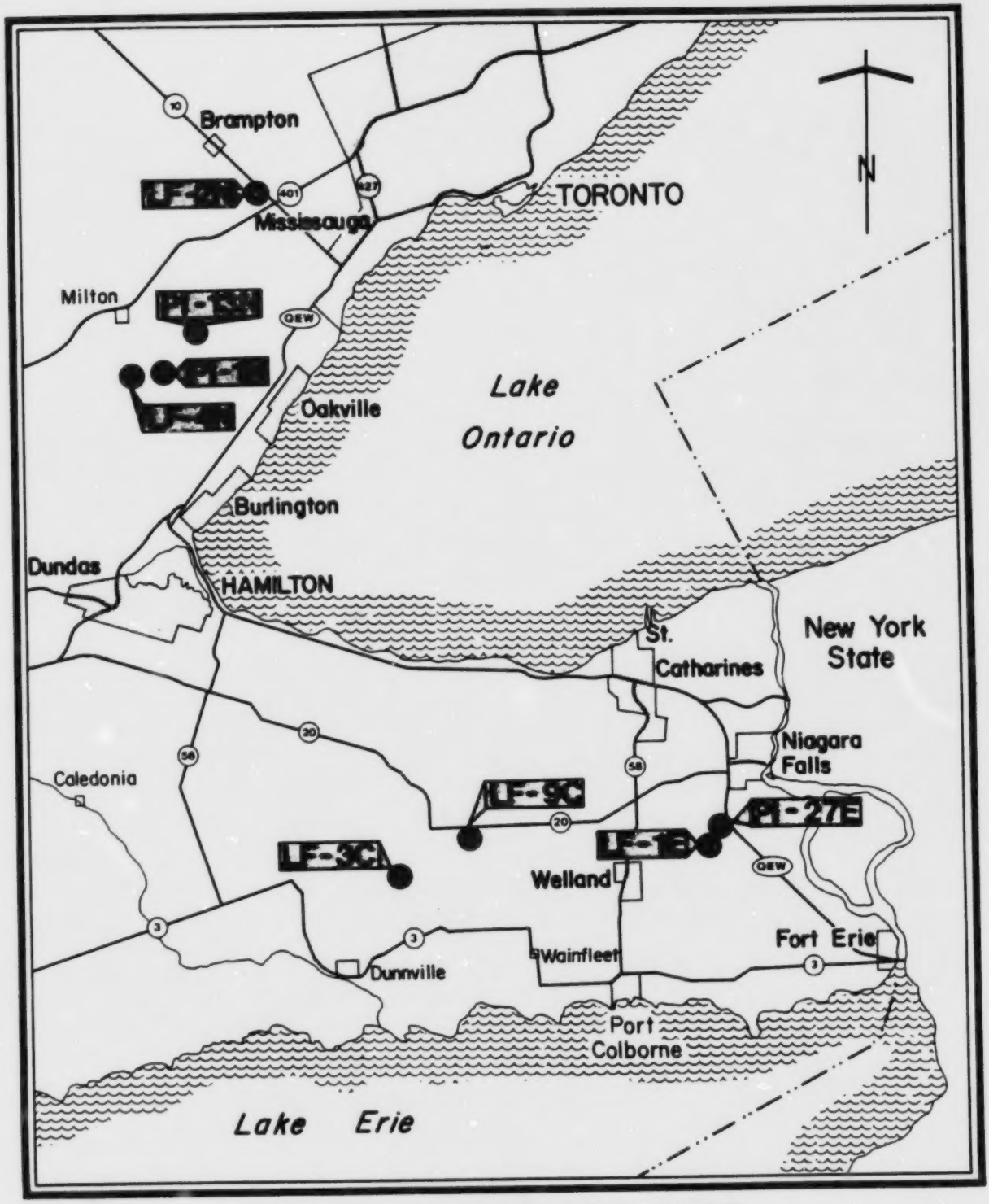


FIGURE 1 LOCATION OF CANDIDATE SITES

2.0 METHODOLOGY

The methodology employed in the collection, compilation, and interpretation of the information base presented in this technical appendix report is described below and is illustrated in Figure 2.

2.1 DATA COLLECTION

The following sources of information were used:

- water well and borehole records; published and unpublished reports, maps, and "open file" reports;
- interviews with government agency personnel and local residents; and
- onsite drilling and field survey results.

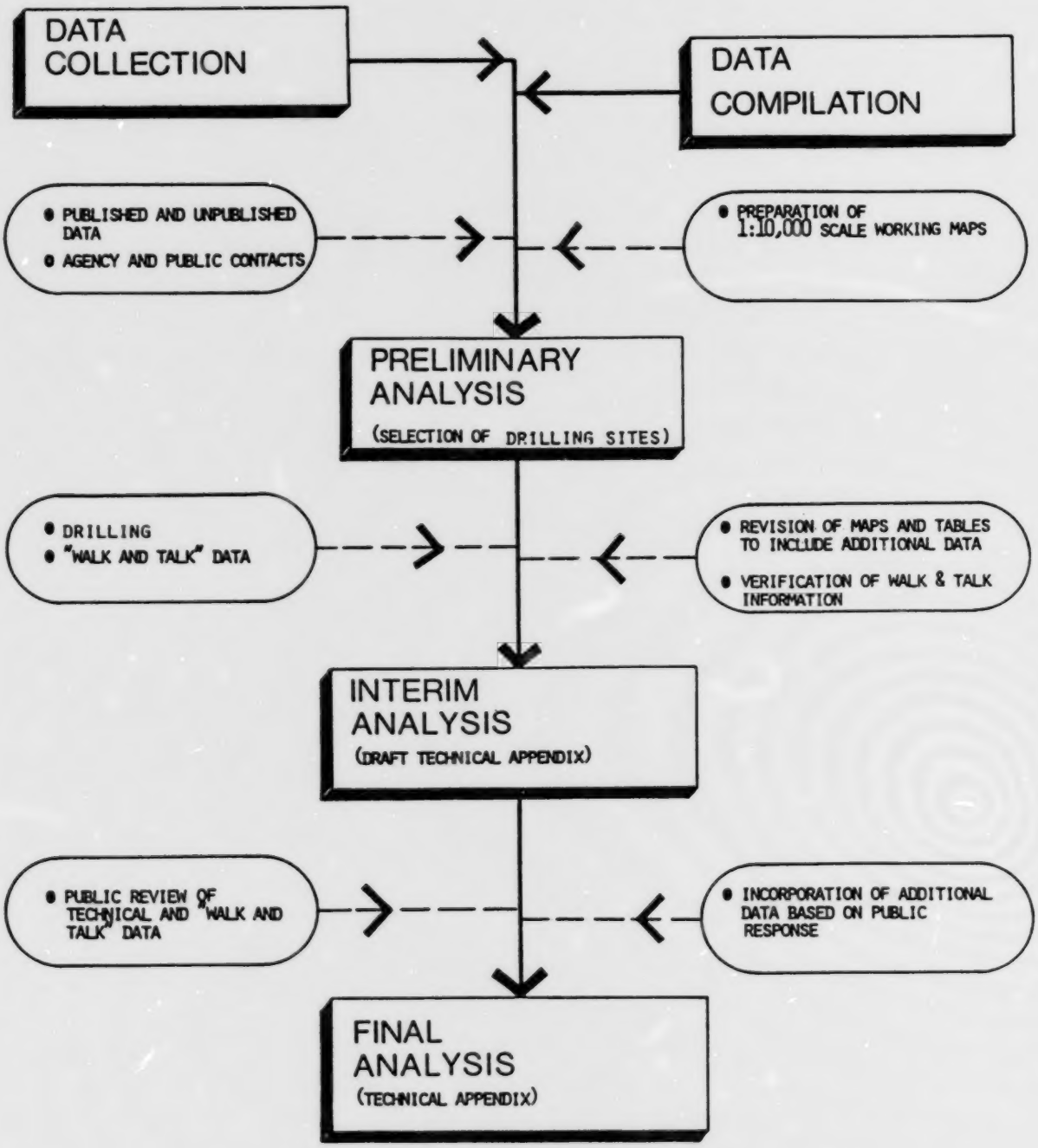
2.1.1 DATA BASE

Numerous reports and maps which contain both regional and local information on the geology and hydrogeology of the candidate sites were assembled during the earlier phases of the site selection process. Reports specific to this site are referenced in the text and are listed in Section 7.0. Data summaries are provided in Section 8.0.

Supplementary information was collected with the co-operation of government and other agencies. This information includes:

Figure 2

Methodology Flow Chart


DATA COLLECTION
DATA COMPILATION
• PUBLISHED AND UNPUBLISHED DATA
• AGENCY AND PUBLIC CONTACTS
• PREPARATION OF 1:10,000 SCALE WORKING MAPS
PRELIMINARY ANALYSIS
(SELECTION OF DRILLING SITES)
• DRILLING
• "WALK AND TALK" DATA
• REVISION OF MAPS AND TABLES TO INCLUDE ADDITIONAL DATA
• VERIFICATION OF WALK & TALK INFORMATION
INTERIM ANALYSIS
(DRAFT TECHNICAL APPENDIX)
• PUBLIC REVIEW OF TECHNICAL AND "WALK AND TALK" DATA
• INCORPORATION OF ADDITIONAL DATA BASED ON PUBLIC RESPONSE
FINAL ANALYSIS
(TECHNICAL APPENDIX)

- copies of original water well records obtained from the Ministry of the Environment,

- copies of borehole information obtained from the Ministry of Transportation and Communications,

- copies of borehole information from previous GLAL hydrogeologic investigations,

- copies of borehole information from hydrogeologic investigations by other consultants.

These data are presented in Section 8.0. Copies of the data are on file.

2.1.2 INTERVIEWS

Additional information regarding site geology and water use was obtained during interviews with government agency personnel and local residents. The results of interviews are presented in the summaries prepared for agency meetings (by GLAL) and on resident interview forms (prepared by Ecologistics Limited). Meetings were held with the local public interest groups made up of residents and other interested individuals who identified items of geologic and hydrogeologic interest. The summaries of meetings and the interview forms are on file. Local water use information summarized from the interview forms is tabulated in Section 8.2.

2.1.3 DRILLING AND FIELD SURVEY RESULTS

Borehole locations were selected based on preliminary analysis of available data and input from the public. Five boreholes were completed at selected locations on the site to investigate

the expected character of the geologic materials. Drilling and sampling procedures are presented in the document entitled "Phase 4A Drilling and Sampling Activities and Protocol" (GLAL 1984a) and the detailed methods employed during this study are summarized in Section 8.6.

The 1984 GLAL drilling program involved the collection of continuous samples from boreholes. These samples were photographed and described in the field, placed in suitable containers, and shipped to the Ontario Geological Survey in Toronto for storage. Split spoon samples were taken at 1.5 m intervals to obtain standard penetration values and samples for moisture content determinations in order to carry out preliminary geotechnical assessments. Detailed borehole logs were prepared based on the field descriptions and on subsequent examination of the samples in storage. These logs are presented as part of the supporting information package in Section 8.3.

2.2 DATA COMPILATION AND ANALYSIS

Data compilation and analysis has proceeded in a staged fashion which is depicted in Figure 2. In the initial work, information such as water well records was compiled in summary tables and illustrated on a series of working maps and cross-sections at a scale of 1:10 000. Maps included plots of:

- data point locations (all sources);
- geology (Ontario Geological Survey maps and reports, constraint mapping results from Phase 3B);
- bedrock elevations (water well and borehole data)

- confining layer thickness (water well and borehole data);
- aquifer thickness (water well data);
- aquifer information (water well data); and
- anomalies such as granular zones (water well and borehole data).

These maps were used to establish the geographic distribution of existing data points and to confirm, at a more detailed scale, the preliminary interpretation of geologic and hydrogeologic conditions as presented in the Phase 3B documentation (GLAL 1984b). Tentative drilling locations were then identified based on this preliminary analysis.

Following the selection of the tentative drilling locations, GLAL personnel met with interested parties to present the results of the preliminary analyses and to discuss the purpose and scope of the Phase 4A program. Additional information on local geologic and hydrogeologic conditions was collected during these meetings. (Water use information provided by the public is incorporated in Section 4.2.3 and in Section 8.2 (Table 5) of this report). Landowners and tenants were contacted at this time to obtain permission to drill on their properties and proposed drill site locations were modified based on local inputs.

A separate data collection program commonly referred to as the "Walk and Talk' survey was undertaken by Ecologistics Limited. During this survey, individual residents were interviewed and the results were recorded in a questionnaire format. Among the multidisciplinary questions were several which were provided by Gartner Lee Associates Limited and

which related specifically to water supply and use. A copy of the water resources questionnaire is provided at the end of Section 8.2. The collection of ground water information and related water use data was limited primarily to the site and to adjacent properties.

With the completion of the drilling and public survey programs, the working maps were revised to incorporate the additional information that was collected. This technical appendix presents an interpretation of geologic, hydrogeologic, and geotechnical conditions at Site PI-1N to date. Draft copies of the data summaries were circulated to local interest groups as a check for completeness and accuracy.

3.0 REGIONAL GEOLOGY AND HYDROGEOLOGY

The geology and hydrogeology of the Halton-Peel area are summarized and discussed in reports prepared for the Ontario Waste Management Corporation (GLAL 1984b,c). This section is based on these reports and the reader is referred to them for more detail and for a complete list of references on which they are based.

3.1 REGIONAL GEOLOGY

3.1.1 BEDROCK GEOLOGY AND OVERBURDEN THICKNESS

Bedrock in the south-central portion of Ontario consists of a series of sedimentary rock formations which dip gently to

the southwest. The various rock formations are consequently exposed on the buried bedrock surface in a series of north-west-southeast trending bands which become progressively younger from northeast to southwest. Figure 3 shows the approximate location of Site PI-1N on a generalized cross-section from the Niagara Escarpment southeastward to Lake Ontario. In the Halton-Peel area the bedrock is the Georgian Bay Formation (grey shale and limestone) in the east and the Queenston Formation (reddish-brown shale) in the west. Generally, the bedrock surface is similar in relief to the present land surface and slopes gently from the Niagara Escarpment to Lake Ontario. Bedrock usually occurs within 10 m of the ground surface and creek valleys are commonly eroded into it. Occasional buried valleys and depressions occur on the bedrock surface and the drift may be substantially thicker where these are infilled. At several locations, water courses have reoccupied portions of bedrock valleys (examples are Sixteen Mile (Oakville) Creek and the Credit River).

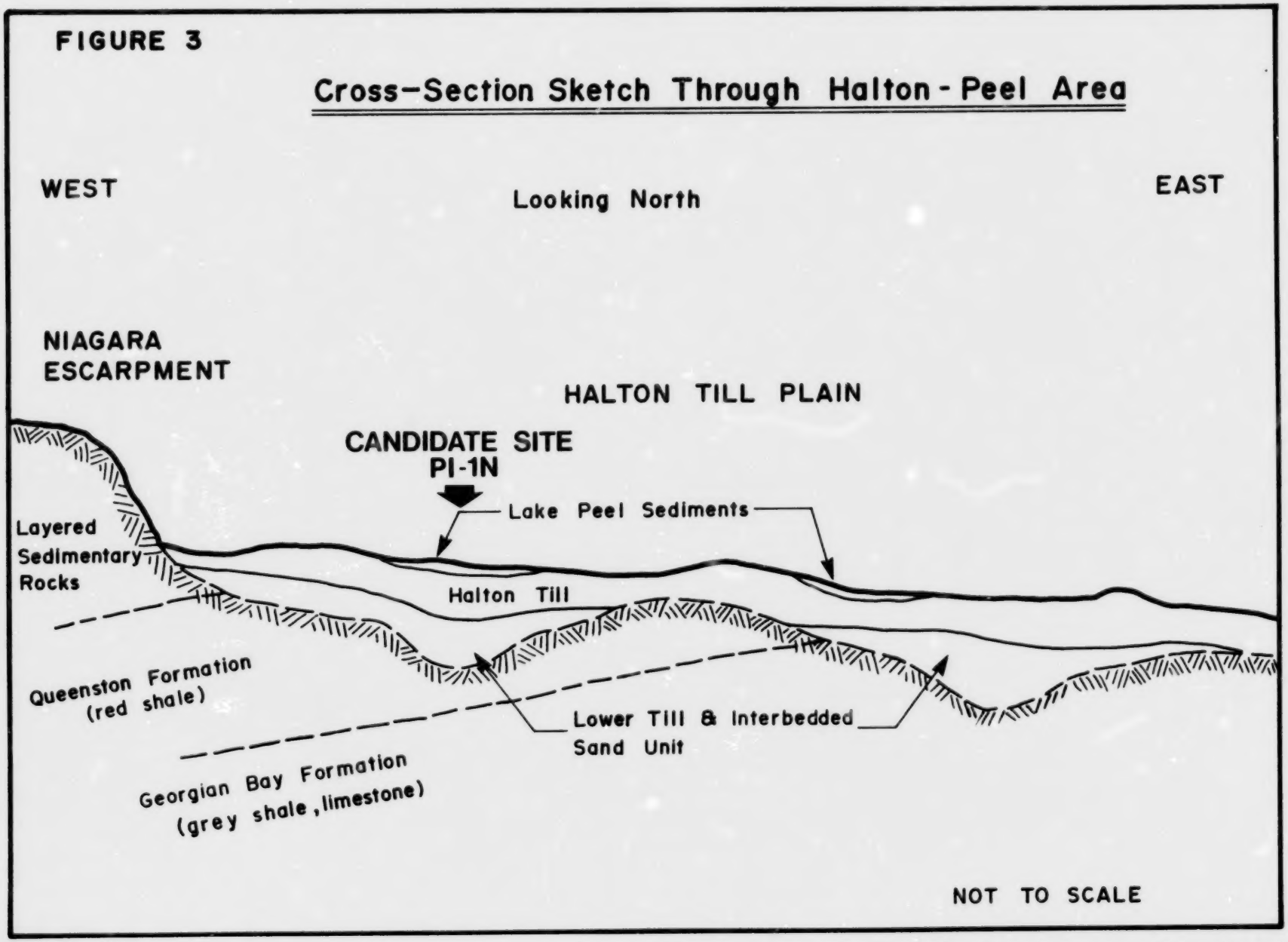
3.1.2 QUATERNARY GEOLOGY

Good geologic exposures are infrequent and there has been little published geologic survey work in the area to date. Available information is summarized and referenced in a previous OWMC report (GLAL 1984c).

Quaternary units are summarized in Figure 3. In view of the lack of detailed geologic studies in the area, only the uppermost till unit (Halton Till) and the intermittent, surficial Lake Peel sediments are referred to by formal names. The underlying deposits are collectively referred to as the 'lower till and interbedded sand unit' on a regional

FIGURE 3

Cross-Section Sketch Through Halton - Peel Area



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basis although locally it may be possible to define sub-units. From oldest to youngest, the units are (1) a group of lower tills and interbedded sands which directly overlie the bedrock, (2) the Halton Till, and (3) the Lake Peel glaciolacustrine sediments. The 'lower till and inter-bedded sand unit' may contain up to three tills. Till textures are most commonly sandy and silty and sand deposits occur within and between tills. It is possible that the Wentworth Till is part of this unit (GLAL 1984c). The Halton Till is a clayey silt to silt till and the surficial Lake Peel sediments consist of an intermittent veneer of sands, silts, and clays.

The geologic events associated with these deposits began with a series of ice sheet advances and retreats which led to the deposition of the 'lower till and interbedded sand unit'. Glaciolacustrine and/or glaciofluvial sands, silts, and clays were deposited between glacial advances and have been preserved between the till sheets at some locations. The last ice advance occurred about 12 000 to 13 000 years ago and laid down the Halton Till. The character of the till suggests a fluctuating ice margin, possibly with a glacial lake in front of the ice. Several subunits are known within the Halton Till and are occasionally separated by thin beds of silt, clay, or sand (GLAL 1984c). A series of shallow, short-lived lakes were formed on the Halton Till during the final melting and retreat of the ice and the Lake Peel sediments were deposited in these lakes. Since the final glacial retreat, the Halton Till and Lake Peel sediments have been subjected to weathering and erosion to produce the present landscape.

3.2 REGIONAL HYDROGEOLOGY

Figure 3 indicates geologic and hydrostratigraphic units which have been used in reports and publications for the Halton-Peel area (GLAL 1984b,c). Each of the units is discussed in a regional context beginning with the bedrock and proceeding through the overburden from oldest to youngest.

The upper fractured portions of both the Queenston and Georgian Bay formations are sources of ground water. Regionally, they are considered poor aquifers as yields are generally low and water quality may be marginal to poor. Where drift aquifers are not present, the bedrock is the only aquifer available. On a regional scale, ground water flow in the upper bedrock is toward Lake Ontario, however local flow patterns may be altered as a consequence of valleys and depressions. Water supplies are usually developed either in the upper fractured portion of the bedrock or in sand and gravel layers which occur between till deposits or directly above the bedrock. These granular deposits are summarized and mapped in previous reports (GLAL 1984b).

The lower tills (which occur within the 'lower till and interbedded sand unit') vary in texture from silty sand to silt and clayey silt. Sand and silt laminae and interbeds are common but vary in thickness, continuity, and hydraulic conductivity. Large diameter bored/dug wells which are completed in this unit likely obtain water from granular interbeds.

The Halton Till is clayey silt to silt in texture and is a hydrostratigraphic unit of regional extent. Ground water movement through it is slow because of its fine texture and low hydraulic conductivity. Dug and bored wells occasionally obtain water supplies within the surficial fractured zone, however most supplies are obtained from the bedrock and from granular zones within the 'lower till and interbedded sand unit'. Alluvium may also provide water supplies to shallow dug and bored wells where such wells are completed in flood plain deposits.

4.0 SITE GEOLOGY AND HYDROGEOLOGY

Geologic and hydrogeologic discussions of Site PI-1N take into account the regional data as well as the new GLAL borehole information. In addition, data from formal and informal field interviews are integrated into this analysis. Figure 4 (in map pocket) provides locations of the cross-sections and the field data presented in this report.

Results from the GLAL borehole program at this comparative evaluation stage are used to confirm the geology and hydrostratigraphy, and to evaluate the predictability and uniformity of subsurface conditions. Hydrogeologic discussions are based on the geology and on such additional sources of information as water well and borehole records and water use data provided by local residents. Table 1 compares local geologic and hydrostratigraphic units for the site and vicinity. This table provides the framework for the discussions that follow, from the bedrock to the surface.

TABLE 1: SUMMARY OF LOCAL GEOLOGIC AND HYDRO-STRATIGRAPHIC UNITS

GEOLOGIC UNIT		HYDROSTRATIGRAPHIC UNIT
LAKE PEEL SEDIMENTS		FRACTURED ZONE (HALTON TILL AND LAKE PEEL SEDIMENTS)
HALTON TILL		CONFINING LAYER
		HALTON TILL
LOWER TILL AND INTER-BEDDED SAND	LOWER TILL	LOWER TILL
	SAND	SAND AQUIFER
	LOWER TILL AND SAND	LOWER TILL, AND SAND AQUIFER
BEDROCK (QUEENSTON SHALE)		BEDROCK AQUIFER

4.1 SITE GEOLOGY

Five continuously sampled boreholes were drilled on Site PI-1N by Gartner Lee Associates Limited in 1984 as part of Phase 4B investigations for OWMC. Also in 1984, Hydrology Consultants Limited supervised the drilling of boreholes at eight locations on the site on behalf of the Region of Halton and Morrison Beatty Limited supervised the drilling of boreholes at four locations on the site on behalf of the Town of Milton. In addition, four boreholes (two on the site) were drilled along Highway 25 by the Ministry of Transportation and Communications in 1969. Boreholes are located in Figure 4 (in map pocket) and borehole logs are presented in Section 8.3.

Geologic cross-sections through the study area are presented in Figures 5 and 6 (in map pocket). Geologic names in the borehole logs (e.g. Halton Till) are used to relate local geology to the established geologic framework and are based on published descriptions.

4.1.1 TERRAIN

Site PI-1N is located on the level to gently rolling Halton Till Plain. It slopes gently to the southeast except where it is dissected by stream erosion. Surface elevations (above sea level) range from about 186 m in the north and northwest to less than 180 m in stream channels near the southern and eastern site boundaries. Drainage in the east is to a tributary of Sixteen Mile Creek and drainage in the west is to Indian Creek.

4.1.2 BEDROCK GEOLOGY AND DRIFT THICKNESS

All GLAL (1984) boreholes encountered Queenston Formation

bedrock which consists of reddish-brown calcareous siltstone and interbedded shale. It is thinly bedded with nearly horizontal bedding planes.

The site overlies a broad buried bedrock valley which generally trends east-west across Site PI-1N and deepens toward the west. In general, the bedrock surface rises toward the Niagara Escarpment. Onsite overburden thicknesses range from less than 8 m in the flood plain of a tributary to Sixteen Mile Creek in the northeast (M.T.C. boreholes), to more than 26 m at Borehole GL84-5 in the west. In general, drift thickness is greatest over the bedrock valley and toward the west in the direction of the deepening valley. The drift is relatively thin beneath the northern third of the site and there is a suggestion of thinning conditions in the south. Much of the central part of the site along the trend of the buried bedrock valley contains about 20 m of drift.

In some places, bedrock is overlain by dense, reddish-brown till with numerous shale fragments and the contact with the bedrock is not clearly defined. This deposit was referred to as the 'shale-till complex' in a previous report (GLAL 1980).

4.1.3 LOWER TILL AND INTERBEDDED SAND UNIT

Up to three clayey silt to silty sand tills were encountered beneath the Halton Till in the 1984 GLAL boreholes. These tills, together with interbedded sand and occasional silt and clay deposits, are referred to here as the 'lower till and interbedded sand unit'. The tills within this unit are distinguished from the Halton Till by their generally coarser

texture and greater textural variability (Section 8.3). They are generally silty to sandy in texture (clayey in Borehole GL84-4) and exhibit textural variability in the form of sandy zones and occasional sand beds ranging to 20 cm in thickness. The contact between the Halton Till and the 'lower till and interbedded sand unit' is usually distinct, however in Borehole GL84-4 the contact is gradational and its placement on the borehole log (and on the cross-section) is tentative.

The basal portion of the 'lower till and interbedded sand unit' is a silty and sandy till with frequent shale fragments at some locations. Numerous sand layers also occur within the 'lower till and interbedded sand unit' and some of these layers may be correlated into one, and in some cases two, sand deposits over portions of the site. These sand layers appear to be more continuous and thicker along the direction of the bedrock valley and may extend beyond the site boundaries. Interpretations of the continuity of these deposits are given in the cross-sections in Figures 5 and 6. The shallower of the sand deposits on the cross-sections is identified as a 'sand' subunit in Table 1 while the deeper sand deposit is included as part of the 'lower till and interbedded sand unit'.

The upper two to three metres of the 'lower till and interbedded sand unit' is a clayey to sandy silt till which contains occasional sand laminae.

4.1.4 HALTON TILL

The surficial till encountered in the GLAL boreholes is the Halton Till. It ranges in texture from silt to clayey

silt and is between 5.6 and 10.7 m thick in Boreholes GL84-4 and GL84-5 respectively. Its upper portion is heavily fractured to depths of about 2 m. Fractures are common to depths of 3 to 4 m and the deepest fracture was noted at a depth of 5.4 m in Borehole GL84-3. Three of the five GLAL boreholes report occasional sand and silt laminae between depths of about 5 to 9 m. These are usually thin and silty and it is doubtful that they are continuous between boreholes.

In Borehole GL84-5 at the western end of the site, the Halton Till is buried beneath a 0.9 m thick layer of glaciolacustrine clayey silt which is probably Lake Peel sediment.

4.1.5 ALLUVIUM

In the study area, alluvium likely underlies the flood plains of Sixteen Mile and Indian creeks. On the site itself, only a small area in the northeast may contain alluvium.

4.1.6 DISCUSSION

The 'lower till and interbedded sand unit' contains sand layers which appear to have continuity principally in an east-west direction along the axis of the bedrock depression. A sandy to clayey silt 'lower till' directly underlies the Halton Till. It also appears to be uniform and predictable along the axis of the bedrock depression but shows increased variability toward the north and south. The Halton Till is generally silty and clayey in texture, contains occasional thin beds of sand and silt, and is relatively uniform and predictable beneath the site.

4.2 SITE HYDROGEOLOGY

The Phase 4A field work incorporates first-hand geologic descriptions and interpretations with the existing data base (primarily water well record and borehole information). Hydrogeologic analyses utilize the geology, the water well and borehole records, information obtained from the public, and information supplied by researchers in similar hydrogeologic settings together with the experience of GLAL staff.

Descriptions of the hydrostratigraphic units, flow systems, ground water use, and potential contaminant pathways are presented in the following sections.

4.2.1 HYDROSTRATIGRAPHY

Four major hydrostratigraphic units occur at Site PI-1N and are illustrated in Table 1. From oldest to youngest (bottom to top) they are: 1) the fractured shale bedrock, 2) the lower till and sand aquifer, 3) the sand aquifer, and 4) the confining layer. The hydrostratigraphic units with aquifer potential at the site include the bedrock and sand deposits below the Halton Till.

The confining layer is comprised of fine-textured deposits with low hydraulic conductivity which are relatively predictable in extent and uniform in texture. The confining layer includes fractured and unfractured portions of the Halton Till and the upper portion of the 'lower till and interbedded sand unit'. The remainder of the 'lower till and interbedded sand unit' is not included in the confining layer because it contains sand layers which appear to be continuous between boreholes and because it is characterized by stratigraphic and textural variability.

4.2.1.1 Bedrock aquifer

The Queenston shale is a common source of water to drilled and bored wells in the study area although there are only two bedrock wells on the site. The bedrock is characterized by low pumping rates and high drawdowns but it is locally important in the absence of other aquifers. It is usually fractured near its upper surface and this is considered to be the preferred zone for well development and for ground water flow. Yields tend to decrease with depth as fractures decrease and water quality is reported to be 'salty' in some deeper wells. Water supplies are usually sufficient for limited domestic and agricultural uses.

Hydraulic conductivities in the Queenston shale at the nearby Oakville Landfill site ranged from 3.7×10^{-6} to 3.3×10^{-9} m/s and have a geometric mean of about 5×10^{-8} m/s (GLAL 1981). Analysis of test pumping data from wells on and in the immediate vicinity of the site using techniques described by Ogden (1965) and Walton (1962) indicate an average hydraulic conductivity of about 6×10^{-6} m/s. This value is substantially larger than the one at the Oakville site, however it is based on local data and is considered representative of the local fractured zone. The porosity of the fractured zone is considered to be about 0.001 and it is considered to be about 5 m thick.

4.2.1.2 Lower till and sand aquifer

This unit contains up to three tills and several sand interbeds. An average hydraulic conductivity of 1×10^{-7} m/s is assigned to this unit to reflect the presence of the sand. Sand interbeds within the 'lower till and sand aquifer' are a source of water supply to drilled and dug/bored wells in the

study area and on the site. Testing of a silty fine sand layer at Site LF-4N (GLAL 1980) indicated a hydraulic conductivity of $1x10^{-7}$ m/s while a value of $5x10^{-4}$ m/s was assigned to a well sorted, medium to coarse sand at another LF-4N location (GLAL 1980). This relatively wide range in hydraulic conductivity is related to texture. In view of the generally silty character of the sandy deposits noted in the 1984 GLAL borehole logs, an average hydraulic conductivity of $1x10^{-6}$ m/s is assigned to the sand layers. This value lies within the range noted above and is in the range of values for silty sand given by Freeze and Cherry (1979).

4.2.1.3 Confining layer

The confining layer includes fine-textured deposits which are relatively uniform and predictable. At Site PI-1N, it extends to the first significant sand layer which occurs either at the base of the Halton Till or within the 'lower till'. The confining layer may include three hydrostratigraphic subunits which are, (i) the lower silt till immediately below the Halton Till, (ii) unfractured Halton Till, and (iii) fractured Halton Till and Lake Peel sediments. Table 2 provides a summary of the thicknesses and selected hydrogeologic parameters for the confining layer.

Part of the 'lower till' (Table 1) is included in the confining layer at Boreholes GL84-1, GL84-4, and GL84-5 which fall along Cross-Section BB' (Figure 6). This cross-section parallels the bedrock depression. The 'lower till' is not included in the confining layer at Boreholes GL84-2 and -3 which occur in the northern and southern areas of the site (and which are farthest from the bedrock depression) because the 'lower till' contains relatively frequent sand layers at

these locations and is considered to be variable and unpredictable. The average hydraulic conductivity of the 'lower till' is considered to be $1x10^{-8}$ m/s which is an order of magnitude greater than that of the unfractured Halton Till. This increase is applied to account for a more sandy texture.

Hydraulic conductivities for the unfractured clayey silt Halton Till are considered to be similar to values reported previously for Site LF-4N (GLAL 1980) where the maximum hydraulic conductivity measured by in situ slug tests was $1x10^{-9}$ m/s. A constant head permeability test on samples of Halton Till (collected from Site LF-4N) in a triaxial laboratory apparatus yielded a value of $5x10^{-10}$ m/s (GLAL 1980).

An average value of $1x10^{-9}$ m/s has been assigned to the unfractured Halton Till based on this information.

The surficial portion of the confining layer (Halton Till) is heavily fractured to a depth of about 2 m and fractures are common to 3 or 4 m. The deepest fracture noted occurred in Borehole GL 84-3 at 5.4 m (Section 8.3). The average depth of fracturing is considered to be approximately 5 m. Freeze and Cherry (1979) note that deposits of clayey or silty till and glaciolacustrine deposits in southern Ontario contain networks of hairline fractures which are essentially vertical and which are responsible for hydraulic conductivities one to three orders of magnitude greater than in unfractured materials. Based on this information, the fractured zone at Site PI-1N is considered to have a hydraulic conductivity of about $1x10^{-7}$ m/s which is two orders of magnitude greater than the

TABLE 2: SUMMARY OF CONFINING LAYER CHARACTERISTICS

BOREHOLES / PARAMETERS	THICKNESS OF CONFINING LAYER SUBUNITS			THICKNESS OF CONFINING LAYER (m)
	LOWER TILL (m)	UNFRACTURED HALTON TILL (m)	FRACTURED HALTON TILL (m)	
GL84-1	3.0	0.7	5.0	8.7
GL84-2	N/A	3.3	5.0	8.3
GL84-3	N/A	1.9	5.0	6.9
GL84-4	2.3	0.6	5.0	7.9
GL84-5	3.1	6.6	5.0	14.7
Average hydraulic conductivity (m/s)	$1x10^{-8}$	$1x10^{-9}$	$1x10^{-7}$	
Average Porosity	0.3	0.3	0.0001	

Notes: - N/A - not applicable

- Porosity values in the unfractured materials reflect intergranular porosity. Additional fracture porosity is present in the fractured zone. The fractures are accompanied by increased hydraulic conductivities with the result that ground water can potentially move more rapidly along fractures.
- 0.2 m fill disregarded in calculations (GL84-2)
- 0.9 m Lake Peel sediment included in Halton Till (GL84-5)

unfractured confining layer. This hydraulic conductivity is applied over the 5 m fractured zone although it is considered more representative of the heavily fractured near-surface zone. Fractures decrease rapidly with depth as they become more tightly closed and less frequent. The fracture porosity is considered to be approximately 0.0001 and is based on Desaulniers' (1981) investigations in similar fine-textured deposits.

4.2.1.4 Discussion

The confining layer consists of the fractured and unfractured Halton Till and of the lower till at some locations. The unfractured Halton Till is less than a metre thick in two GLAL boreholes and could be absent at some locations in view of the variability in thickness of this unit. It is also possible that the lower till may not be suitable for inclusion in the confining layer at other locations.

4.2.2 GROUND WATER FLOW REGIME

Infiltration is the source of ground water and differences in hydraulic head provide the driving force for ground water flow systems. At Site PI-1N there is potential for lateral fracture flow in the saturated portion of the fractured zone. Directions of flow will follow the slope of the water table and flow will occur along interconnected fractures. Ground water flow in the unfractured portion of the confining layer will be primarily downward as vertical gradients on the site substantially exceed horizontal gradients.

The water table occurs in the fractured zone and its shape is generally a reflection of topography. Shallow flow within the fractured zone is most active over a narrow zone

which occurs within about 2 m of the surface and which varies seasonally with the water table. Since fractures and fracture flow diminish with depth, it is considered that fracturing has very little effect on flow below depths of about 5 m. Movement in the fractured zone is considered to be mainly lateral with rates and directions of flow dependent on elevation differences in the water table. Flow will be toward local discharge areas such as drainage channels (tributaries of Sixteen Mile and Indian creeks) and topographic lows. The average lateral flow rate in the fractured zone is estimated to be about 8×10^{-6} m/s (250 metres per year) based on parameters noted in Section 4.2.1.3 and a water table gradient of 0.008. Fracture flow rates are unrealistically large if the rates are interpreted as 'straight-line' flow pathways because fracture interconnections are generally complex and interconnections that do exist are usually indirect.

Table 3 presents a summary of vertical rates of flow in the subunits which comprise the confining layer. A methodology for calculating flow rates for layered situations is given in Freeze and Cherry (1979) and is reproduced in Section 8.4 along with a sample calculation. An average downward hydraulic gradient across the confining layer of 0.2 is used in flow rate calculations and this was obtained by comparing reported static water levels in onsite and adjacent water wells with a water table assumed to be at ground surface. This method results in a steeper gradient than actually exists. Monitors in the western portion of the study area (GLAL 1980) indicate downward gradients of less than 0.1 under similar conditions.

TABLE 3: ESTIMATED VERTICAL FLOW RATES IN THE CONFINING LAYER

BOREHOLE	UNFRACTURED LOWER TILL AND HALTON TILL (m/s)	FRACTURED HALTON TILL (m/s)
GL84-1	6×10^{-9}	2×10^{-5}
GL84-2	2×10^{-9}	5×10^{-6}
GL84-3	2×10^{-9}	7×10^{-6}
GL84-4	6×10^{-9}	2×10^{-5}
GL84-5	1×10^{-9}	4×10^{-6}

Notes: Multiply by 3.15×10^{7} for flow rates in metres per year.

The lower till is not included in the confining layer in Boreholes GL84-2 and GL84-3.

Inspection of Table 3 indicates that estimated ground water velocities in the fractured zone are three to four orders of magnitude greater than in the unfractured zone and that the unfractured confining layer is the dominant zone which retards ground water flow.

A more accurate assessment of ground water flow rates through the confining layer using advection and diffusion caloulations is contained in Appendix A of the report entitled "Site Selection Process; Phase 4A, Selection of Preferred Site(s), Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

Ground water movement in the bedrock beneath the study area is primarily lateral and occurs principally within the upper fractured zone. An average gradient of 0.01, an average hydraulic conductivity of $5x10^{-6}$ m/s, and an average porosity of 0.001 result in an estimated average ground water flow rate of approximately 1500 metres per year.

As indicated previously, fracture flow rates may be unrealistically large if they are interpreted over 'straight-line' distances since fracture connections are usually complex and may be indirect or poorly developed. Water level data from bedrock wells are unevenly distributed and interpretations of flow directions and gradients are therefore tentative. It is expected that the general flow direction in the area is toward Lake Ontario, however local flow may be influenced by the east-west trending bedrock valley.

4.2.3 GROUND WATER USE

Water use information is based on water well record data and on information provided by residents and landowners on the site and on adjacent properties.

4.2.3.1 Availability

Water supplies for domestic, stock, and general agricultural purposes are obtained from drilled wells, dug or bored wells, and occasionally from cisterns and ponds. Water use information is summarized according to source in Figure 8 (in map pocket) and is supported by Table 5 in Section 8.2.

Based on water well records and field information surveys, it appears that both drilled and dug/bored wells are important sources of water supply in the study area. Of approximately 100 wells on record with the Ministry of the Environment, about 40% are dug or bored and about 60% are drilled (Figure 8 and Table 4). The majority of the drilled wells are completed in the bedrock (about 85%), while most of the dug or bored wells (about 70%), obtain water from the overburden. Bedrock wells are most frequent in areas of shallower overburden to the north, east, and south.

Available data indicate that most wells in the study area have relatively low yields. However, only six residents indicated water shortages and most residents obtain sufficient water to meet domestic and agricultural needs. Eight persons reported using cisterns for laundry, toilet, household or livestock watering purposes, or as backup systems for their wells. Eight ponds are reported on the site and some of these are used for livestock watering and agricultural uses.

4.2.3.2 Quality

Only a few wells in the study area are reported to have 'salty', 'mineralized','sulphurous', or 'non-potable' water and most of these are deeper bedrock wells. Some are unused or abandoned and others are used primarily for agricultural purposes. Most MOE water well logs report 'fresh' water and most of the residents who were interviewed indicated that their water was 'hard' but potable.

4.2.4 POTENTIAL CONTAMINANT PATHWAYS

In general, there are two hydrogeologic pathways by which contaminants can potentially leave this site; these are (1)

natural pathways along ground water flow systems and (2) man-made pathways along abandoned and unplugged wells, tile drains, and service trenches. Flow systems are discussed in Section 4.2.2.

Efforts have been made to identify and locate man-made structures on the site such as water wells, gas wells, tile drainage systems, pipelines, and excavations. Such structures could act as pathways along which contaminants could potentially move. Abandoned or improperly sealed wells which penetrate the confining layer could provide access to underlying aquifers while granular trench backfill and drainage tiles provide an offsite pathway to surface water and shallow ground water.

There are about twenty wells on the site. About fifteen are dug/bored overburden wells and five are reportedly abandoned (four are located on one property). Gas wells are not common in this area and Ministry of Natural Resources records indicate none on the site. Present information indicates that there is no tile drainage on the site.

Excavations are limited mainly to the immediate vicinity of buildings, however an east-west oil pipe line crosses the northern part of the site. The presence of buried service trenches along roads and railroads was not investigated.

5.0 GEOTECHNICAL CONSIDERATIONS

This section of the report provides a preliminary assessment of Site PI-1N from a soils engineering viewpoint. The geologic setting is described in detail in Section 4.0.

The geologic data base has been supplemented by standard penetration split spoon tests taken at approximately 1.5 m intervals in each of the five GLAL boreholes. The standard penetration (N) values have been used as a guide in estimating the relative density and consistency of the various soils. Shear strengths noted here are estimates based on empirical relationships between blow counts and shear strengths. Moisture contents are presented along with N values on the borehole logs (Section 8.3).

A desiccated crust, approximately 3 to 5 m thick, is associated with the surficial portion of the Halton Till over most of the site. This crust is not evident in the vicinity of Borehole GL 84-2 based on the available data. As indicated by N values of 30 to 70 (blows per 0.3 m), the desiccated crust is hard. These N values relate to an undrained shear strength in excess of 200 kPa. In situ moisture contents ranged from 10 to 16%.

There is a weaker stratum 2 to 5 m thick below the desiccated crust (partially within the Halton Till and partially within the lower till) except in Borehole GL 84-2 where the consistency remains hard. The relative density is

compact with N values ranging from 12 to 32. This stratum is thinnest and has the highest density in the vicinity of Borehole GL 84-3.

In Borehole GL84-2 the N values range from 23 to 47 indicating the soil is very stiff to hard. Undrained shear strengths are likey to be from 150 to in excess of 200 kPa. In situ moisture contents range from 9 to 17%.

Beneath the weaker stratum in Borehole GL 84-5 there is a zone of typically hard material which is also part of the Halton Till. (This zone is geotechnically similar to the Halton Till in Borehole GL 84-2). N values are greater than 30 and the corresponding undrained shear strength exceeds 200 kPa.

The lower tills below the weaker stratum are very dense with N values greater than 50. In situ moisture contents are typically lower than 10% though locally higher values were recorded (usually in association with finer textured strata). Layers of very dense, saturated sand occur within the lower tills.

Preliminary assessments based on borehole data indicate that geotechnical conditions are generally adequate for foundations and excavations. All geotechnical aspects will require further investigation during Phase 4B work on the preferred site.

The allowable bearing pressure is generally adequate for light and medium weight structures with shallow strip or conventional pad footings. As a guide, an allowable bearing

pressure of 300 kPa can be adopted for footings founded in the upper 1.5 m of the desiccated crust. For footings founded in the weaker stratum below the desiccated crust, the allowable bearing pressure is lower, possibly about 200 kPa as a guide. Settlement of these structures should not exceed tolerable limits. For heavy structures, it will likely be necessary to transfer loads to the lower till where greater allowable bearing pressure exist. Settlement within the lower tills should not be a problem.

Temporary excavations can be safely carried out to considerable depth within the tills at 1:1 side slopes with the following exceptions. Preliminary calculations indicate that excavations terminating within 2 to 3 m of sand layers may be subject to heave. If excavations intersect saturated sand layers, ground water control will be necessary.

In general, subsoils on the site have good handling and workability characteristics. Wet weather handling may require some special attention due to the clay content. Trafficability is also generally good except during wet weather.

6.0 SUMMARY

Site PI-1N is located on the gently rolling Halton Till Plain within the corporate limits of the Town of Milton. The site is underlain by Queenston shale and is traversed by a buried bedrock valley which trends in an east-west

direction and deepens toward the west. Overburden thicknesses range from less than 10 to more than 25 m and are greatest over the bedrock valley. The overburden is comprised of a group of lower tills and interbedded sand layers overlain by Halton Till. Ground water supplies are obtained from the bedrock and from the various sand layers.

The confining layer includes fractured and unfractured Halton Till and an underlying silt till in that part of the site underlain by the bedrock valley. The average thickness of the fractured zone is about 5 m and there is potential for lateral ground water flow in the saturated portion of the fractured zone. The unfractured Halton Till is the dominant hydrogeologic unit retarding ground water flow with annual vertical flow rates estimated to be 0.02 m. Confining layer thicknesses range from 6.9 to 14.7 m in GLAL boreholes however the thickness of the unfractured Halton Till ranges from 0.6 to 3.3 m thick.

Dug and bored wells, drilled wells, cisterns, and ponds are sources of water supply in the study area. Slightly less than half the wells are dug and bored, and bedrock is the source of supply to about three quarters of the wells in the study area. Wells generally yield sufficient water for household and agricultural needs but cisterns and ponds are sometimes used to provide additional or alternate supplies. Deeper bedrock wells sometimes report poor quality water.

Potential contaminant pathways for offsite movement include natural ground water flow systems and man-made conduits through the confining layer. Natural ground water flow tends to be retarded by the confining layer, however

there are about 30 known wells on the site which penetrate the confining layer.

The surficial portion of the Halton Till forms a desiccated crust over most of the site and thicknesses up to 5 m were noted. An underlying weaker stratum (2 to 5 m thick) exists at most locations and is underlain by dense to very dense deposits. Adequate bearing pressures are generally available in the desiccated crust for light and medium weight structures with shallow strip and conventional pad footings. Adequate bearing pressure will be less for footings founded in the underlying weaker stratum. For heavy structures, it will be necessary to transfer loads to the 'lower till and interbedded sand unit'. Temporary excavations can be safely carried out to considerable depths within till deposits at side slopes of 1:1 except where saturated sands occur and possibilities of heave exist. Where excavations encounter saturated sand layers, ground water control will be required. Subsoils generally have good handling, trafficability, and workability characteristics, however wet conditions may require some special attention.

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8.0 SUPPORTING INFORMATION

8.1 SUMMARY OF WATER WELL DATA, TABLE 4

8.2 SUMMARY OF SITE INTERVIEW (WALK AND TALK) DATA, TABLE 5

8.3 BOREHOLE LOGS

8.4 SUPPORTING CALCULATIONS AND METHODS

8.5 GLOSSARY OF SELECTED TERMS

8.1 SUMMARY OF WATER WELL DATA

Copies of original Water Well Records obtained from the Ontario Ministry of the Environment (MOE) were used for the following data summary and are on file.

Water well locations are shown in Figure 4 (in map pocket).

Measurements, dimensions and quantities on the Water Well Records are in Imperial units but are presented in metric units in the summary.

Water well locations (Figure 4) were plotted on 1:10 000 scale maps for this project and elevations were re-estimated based on the more accurate contours on these maps. Well elevations are above sea level (ASL) and are estimated to the nearest metre.

Well records are arranged in numerical order.

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	DRILLERS MATERIALS DESCRIPTION
88	SPECK, C. CON.2 DSN, LOT 1 TOWN OF MILTON (PREV. NELSON TWP.)	175	NOV 1959	15.2	15.2	FRESH	18.3	9.4	18.3	0.2	DOMESTIC	0.0 1.5 16.8	1.5 16.8 18.3	BROWN CLAY GREY CLAY GRAVEL
89	SANDERSON, HAROLD CON 2 DSN, LOT 1 TOWN OF MILTON (PREV. NELSON TWP.)	175	AUG 1967	15.9	22.9	FRESH	21.9	6.1	22.9	--	DOMESTIC	0.0 4.3 16.8 21.3	4.3 16.8 21.3 24.4	BROWN CLAY GREY CLAY REDDISH BROWN GRAVELLY CLAY RED SHALE
623	PATTERSON, HAROLD CON 7 NS, LOT 1 TOWN OF MILTON (PREV. NELSON TWP.)	177	APR 1962	15.2	11.6	FRESH	10.3	4.9	12.8	0.2	DOMESTIC	0.0 3.7 8.1 10.1	3.7 8.1 10.1 12.8	LIGHT BROWN CLAY GREY CLAY, AND GRAVEL RED CLAY RED SHALE
624	PATTERSON, A. CON 7 NS, LOT 1 TOWN OF MILTON (PREV. NELSON TWP.)	177	MAY 1966	15.9	11.9	FRESH	10.4	6.1	14.0	0.1	DOMESTIC	0.0 4.3 7.3 11.9	4.3 7.3 11.9 14.0	BUFF CLAY GREY CLAY RED CLAY RED SHALE
625	IBBETSON, N. CON. 7 NS, LOT 1 TOWN OF MILTON (PREV. NELSON TWP.)	178	OCT 1966	15.9	10.7	FRESH	17.8	10.1	17.7	0.2	DOMESTIC	0.0 4.9 12.8 17.7	4.9 12.8 17.7	BROWN CLAY GREY CLAY GREY CLAY AND GRAVEL RED SHALE
626	SHERIN, JIM CON. 7 NS, LOT 1 TOWN OF MILTON (PREV. NELSON TWP.)	177	JAN 1966	15.9	12.8	FRESH	9.1	4.6	19.8	0.0	DOMESTIC	0.0 1.2 8.8	1.2 8.8 19.8	BROWN CLAY RED CLAY RED SHALE
627	SHERIN, JIM CON. 7 NS, LOT 1 TOWN OF MILTON (PREV. NELSON TWP.)	177	FEB 1966	15.9	12.8	FRESH	10.1	4.6	13.7	0.1	DOMESTIC	0.0 1.2 9.8	1.2 9.8 13.7	BROWN CLAY RED CLAY RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	DRILLERS MATERIALS DESCRIPTION
2228	TRAFALGAR PARKS BOARD CON. 2 DSN, LOT 26 TOWN OF OAKVILLE (PREV. TRAFALGER TWP.)	155	APR 1960	15.9	1.5 2.1 3.7 7.0	-- -- FRESH FRESH	3.7	0.9	4.3	2.7	PUBLIC SUPPLY	0.0 0.6 1.5 1.8	0.6 1.5 1.8 7.3	DARK BROWN TOPSOIL BROWN CLAY, AND SMALL STONES BROKEN SHALE (RED) RED SHALE
2230	JANSEN, J. CON. 2DSN, LOT 27 TOWN OF OAKVILLE (PREV. TRAFALGAR TWP.)	174	MAY 1962	15.2	16.5	FRESH	16.2	13.7	28.7	0.1	DOMESTIC	0.0 5.5 14.3 15.2	5.5 14.3 15.2 28.7	BROWN CLAY GREY CLAY RED CLAY AND SMALL AMOUNT OF GRAVEL RED SHALE
2231	KESSELS, WILLIAM CON 2 DSN, LOT 27 TOWN OF OAKVILLE (PREV. TRAFALGAR TWP.)	173	JUN 1966	15.9	19.2	FRESH	18.3	14.9	29.3	0.1	DOMESTIC	0.0 5.2 7.3 18.0	5.2 7.3 18.0 29.3	BUFF CLAY BLUE CLAY DULL RED CLAY RED SHALE
2232	COWAN, FRANK CON 2 DSN, LOT 29 TOWN OF OAKVILLE (PREV. TRAFALGAR TWP.)	183	MAR 1959	15.9	15.5	FRESH	--	5.5	15.2	0.2	STOCK DOMESTIC	0.0 9.1 14.0	9.1 14.0 16.2	CLAY BLUE CLAY SHALE
2234	BREENER, JOE H. CON. 2 DSN, LOT 29, TOWN OF MILTON (PREV. TRAFALGAR TWP.)	182	OCT 1967	76.2	14.0	FRESH	14.3	6.1	--	0.1	DOMESTIC	0.0 3.7 13.7 14.0	3.7 13.7 14.0 --	TAN BROWN SOIL GREY CLAY, SOME REDDISH COARSE SAND AND WATER RED SHALE ON THE BOTTOM
2236	DEVOGEL, C. CON. 2 DSN, LOT 30 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	183	AUG 1960	15.2	14.9	FRESH	--	5.5	22.3	0.1	DOMESTIC	0.0 10.7 14.9 15.2	10.7 14.9 15.2 22.3	GREY CLAY BROWN CLAY GRAVEL RED SHALE
2241	CORE, R. CON 2 DSN, LOT 31 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	183	JUL 1954	15.9	15.2	FRESH	3.7	6.1	--	0.1	DOMESTIC	0.0 6.7 10.1	6.7 10.1 16.2	DUG WELL CLAY CLAY RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	DRILLERS TO (m)	DRILLERS MATERIALS DESCRIPTION
2246	CORE, R.P. CON 2 DSN, LOT 31 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	183	FEB 1957	15.9	14.6	FRESH	14.3	3.0	13.7	--	DOMESTIC	0.0 11.0	11.0 16.8	CLAY RED SHALE
2247	SOKALUK, M. CON. 2 DSN, LOT 31. TOWN OF MILTON (PREV. TRAFALGAR TWP.)	182	NOV 1958	15.9	17.4	FRESH	15.2	2.7	15.2	0.4	DOMESTIC	0.0 7.0 10.7 14.6	7.0 10.7 14.6 18.0	CLAY BLUE CLAY CLAY AND STONES RED SHALE
2248	CORE, R. CON 2 DSN, LOT 31 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	183	NOV 1958	15.9	18	FRESH	15.8	3.7	15.2	0.1	DOMESTIC	0.0 6.7 10.7 14.6	6.7 10.7 14.6 18.9	CLAY BLUE CLAY REDDISH CLAY RED SHALE
2251	KOPPERS, F. CON 2 DSN, LOT 31 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	181	JUN 1959	15.9	15.2	FRESH	14.7	4.9	14.9	0.1	DOMESTIC	0.0 7.6 13.7	7.6 13.7 18.3	CLAY BLUE CLAY RED SHALE
2253	KNOFLACH, FRANK CON 2 DSN, LOT 31 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	181	DEC 1963	12.7	19.5	FRESH	13.4	2.7	4.3	0.2	DOMESTIC	0.0 0.6 12.2	0.6 12.2 19.8	TOPSOIL BROWN CLAY WITH FEW PEBBLES RED SHALE (ROCK)
2254	KNOFLACH, FRANK CON 2 DSN, LOT 31 TOWN OF MILTON (PREV. TRAFAGAR TWP.)	181	MAR 1964	12.7	15.5	FRESH	13.7	5.5	7.0	0.2	DOMESTIC	0.0 0.6 13.1 14.0	0.6 13.1 14.0 16.2	TOPSOIL BLUE CLAY SAND (RED SHALE) ROCK
2257	STRAESSLE, K. CON 2 DSN, LOT 32 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	183	OCT 1956	15.9	12.2 21.3 25.0	-- -- SALTY	9.1	4.3	22.9	0.2	DOMESTIC	0.0 1.5 5.5 8.2 15.2	1.5 5.5 8.2 15.2 25.3	BLACK TOPSOIL LIGHT BROWN CLAY GREY CLAY SOFT RED SHALE HARD RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN	DATE DRILLED YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	DRILLERS MATERIALS DESCRIPTION
2261	MARSCHALL, JIM CON 2 DSN, LOT 33, TOWN OF MILTON (PREV. TRAFALGAR TWP.)	182	NOV	1961	76.2	15.8	FRESH	16.2	6.1	--	0.1	DOMESTIC	0.0	3.7	TOP BROWN SOIL
													3.7	7.3	GREY CLAY
													7.3	9.1	REDDISH CLAY
													9.1	15.8	RED SHALE, WATER FOUND ON BOTTOM
2262	SOUTER, TOM CON 2 DSN, LOT 33 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	181	SEP	1967	15.9	15.2	FRESH	14.3	2.7	17.4	0.1	DOMESTIC	0.0	4.9	BUFF CLAY
													4.9	12.2	GREY CLAY (SOME GRAVEL)
													12.2	14.6	DULL RED CLAY SOME GRAVEL
													14.6	17.4	RED SHALE
2263	MEeUSSEN, H. CON 2 DSN, LOT 34 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	180	JUN	1960	15.2	12.2	FRESH	17.8	4.6	18.0	0.1	DOMESTIC	0.0	12.2	BROWN CLAY
													12.2	17.4	GRAVEL, CLAY
													17.4	18.0	FINE GRAVEL
													18.0	18.3	RED SHALE
2264	KURTZ, A. CON 2 DSN, LOT 34 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	180	OCT	1960	15.2	17.7 19.2	-- FRESH	19.1	4.8	19.2	0.3	DOMESTIC	0.0	13.7	BROWN CLAY
													13.7	17.7	RED CLAY
													17.7	19.2	GRAVEL
2265	VANDERCAMP, TONY CON 2 DSN, LOT 34 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	180	JAN	1964	15.9	9.1	FRESH	11.6	6.1	9.8	0.4	DOMESTIC	0.0	9.1	BLUE CLAY
													9.1	11.6	GRAVEL
2267	GAREAU, LEO CON 2 DSN, LOT 35 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	175	OCT	1961	15.9	21 3	FRESH	18.3	9.1	21.3	--	DOMESTIC	0.0	18.3	RED CLAY
													18.3	21.3	RED SHALE
2268	ADAM CONSTRUCTION CON 2 DSN, LOT 35, TOWN OF MILTON (PREV. TRAFALGAR TWP.)	176	APR	1962	15.2	14.6	FRESH	17.1	7.0	17.1	0.2	DOMESTIC	0.0	3.7	BROWN CLAY
													3.7	14.6	GREY CLAY
													14.6	17.1	RED CLAY AND GRAVEL
													17.1	--	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	TO (m)	MATERIALS DESCRIPTION
2271	SECORD, VICTOR CON 2 DSN, LOT 35 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	176	NOV 1964	76.2	22.6	FRESH	22.9	12.2	--	0.1	DOMESTIC	0.0	5.5	TOP BROWN SOIL
												5.5	19.8	GREY CLAY
												19.8	21.9	REDDISH CLAY
												21.9	22.6	SAND AND WATER SOME GRAVEL ON BOTTOM
												22.6	--	RED SHALE ON BOTTOM
2453	CRIPPS, H.H. CON 1 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	175	JUN 1962	15.2	10.7	FRESH	12.5	5.5	12.5	0.7	DOMESTIC	0.0	5.5	BROWN CLAY
												5.5	10.7	GREY CLAY
												10.7	11.6	CLAY AND GRAVEL
												11.6	12.5	GRAVEL
2454	MARSHALL, JIM CON 1 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	181	JUN 1963	76.2	16.5	FRESH	16.8	9.1	--	0.5	STOCK DOMESTIC	0.0 3.7	3.7 15.8	TOP BROWN SOIL REDDISH CLAY
												15.8	16.5	GRAVEL AND WATER
2455	ROCKLIFFE, M. CON 1 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	184	FEB 1967	13	19.8 26.8	FRESH FRESH	15.2	6.1	27.4	0.2	DOMESTIC	0.0	4.9	BROWN CLAY
												4.9	8.5	BLUE CLAY
												8.5	13.7	RED CLAY
												13.7	29.0	RED SHALE ROCK
2456	MCGINNES JR., BOB CON 1 NS, LOT 2 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	178	AUG 1959	15.2	11.6	FRESH	6.4	3.7	11.6	0.3	DOMESTIC	0.0	5.5	BROWN CLAY
												5.5	13.1	RED SHALE
2457	HUETTEN, HENRY CON 1 NS, LOT 2 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	185	APR 1965	76.2	15.2	FRESH	18.3	10.7	--	0.0	DOMESTIC	0.0	6.1	TOP BROWN SOIL
												6.1	10.7	REDDISH CLAY
												10.7	15.2	RED SHALE
												15.2	18.0	SOME WATER COMING FROM RED SHALE IN PARTS GREY SHALE
2458	JANICKI, J. CON 1 NS, LOT 2 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	184	JUN 1965	15.9	21.3	FRESH	10.4	2.7	22.9	0.1	DOMESTIC	0.0	1.8	BROWN CLAY
												1.8	9.1	BLUE CLAY
												9.1	22.9	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	TO (m)	MATERIALS DESCRIPTION
2459	GAMCKI, JOHN CON 1 NS, LOT 2 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	184	JUL 1966	76.2	16.5	FRESH	16.8	7.6	--	0.2	DOMESTIC	0.0	5.5	TOP BROWN SOIL
												5.5	11.6	REDDISH CLAY
												11.6	16.5	RED SHALE, WATER COMES FROM BOTTOM
2460	KOLLER, H. CON 1 NS, LOT 3 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	180	AUG 1951	15.2	18.9	FRESH	12.2	6.1	--	--	STOCK DOMESTIC	0.0 12.2	12.2 18.9	BLUE CLAY RED ROCK
2461	MCFADDEN CON 1 NS, LOT 5 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	181	MAR 1960	76.2	15.2	FRESH	15.8	--	--	--	DOMESTIC	0.0	3.7	BROWN CLAY
												3.7	15.2	GREY CLAY
												15.2	15.8	COARSE GRAVEL
2462	LAWRENCE, D. CON 1 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	187	JAN 1955	15.9	25.6	MINERAL	18.3 (PULLED)	5.5	--	--	ABANDONED	0.0	6.7	BLUE CLAY
												6.7	18.3	CLAY, SAND, GRAVEL
												18.3	25.9	RED SHALE
2463	LAWRENCE, D. CON 1 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	187	JAN 1955	15.9	21.9	MINERAL	19.5	5.5	--	<0.1	DOMESTIC	0.0	7.3	BLUE CLAY
												7.3	18.9	CLAY, SAND, AND STONE
												18.9	22.3	RED SHALE
2470	GILL, H. CON 2 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	182	JUL 1957	15.9	17.7	SALTY	13.7	2.4	17.7	--	--	0.0	1.5	CLAY
												1.5	6.1	SAND AND CLAY
												6.1	10.1	BLUE CLAY
												10.1	13.7	SAND, GRAVEL, RED CLAY
												13.7	18.3	RED SHALE
2471	GILL, H. CON 2 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	182	AUG 1957	15.9	16.5	FRESH	13.7	2.4	15.2	--	DOMESTIC	0.0	1.5	CLAY
												1.5	6.1	SAND AND CLAY
												6.1	10.1	BLUE CLAY
												10.1	13.7	SAND, GRAVEL, RED CLAY
												13.7	17.4	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	DRILLERS TO (m)	DRILLERS MATERIALS DESCRIPTION
2472	WRIGHT, F.G. CON 2 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	182	FEB 1961	15.2	16.8	FRESH	11.4	6.1	8.5	0.1	DOMESTIC	0.0	11.6	BLUE CLAY
												11.6	18.3	RED SHALE (ROCK)
2473	DUNHAM, WILHELMINA CON 2 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	182	MAR 1961	15.2	16.8	FRESH	11.3	6.1	8.5	0.1	DOMESTIC	0.0	11.3	BLUE CLAY
												11.3	18.0	RED SHALE (ROCK)
2474	FISHER, V. CON 2 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	185	APR 1966	76.2	14.0	FRESH	14.3	6.1	--	0.2	DOMESTIC	0.0	4.6	TOP BROWN SOIL
												4.6	11.0	RED CLAY
												11.0	14.0	RED SHALE, WATER COMES FROM BOTTOM
2475	TASKER, H. CON 2 NS, LOT 3 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	183	OCT 1963	76.2	17.1	FRESH	17.4	9.1	--	0.1	DOMESTIC	0.0	3.7	TOP BROWN SOIL
												3.7	16.5	RED CLAY
												16.5	17.1	SAND AND WATER
												17.1		RED SHALE ON THE BOTTOM
2476	MARTIN, WATT CON 2 NS, LOT 4 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	183	AUG 1964	15.2	21.6	FRESH	22.9	8.2	13.7	0.8	DOMESTIC	0.0	2.1	GREY CLAY
												2.1	17.1	REDDISH CLAY
												17.1	20.7	GREY CLAY
												20.7	22.9	GREY CLAY AND GRAVEL
2477	LUKEWSKI, A. CON 2 NS, LOT 4 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	183	JUL 1964	16.1	18.3	FRESH	17.4	3.0	17.7	0.8	DOMESTIC	0.0	8.5	BROWN CLAY
												8.5	12.8	CLAY AND SAND
												12.8	15.5	RED CLAY AND SAND
												15.5	18.9	RED SHALE
2478	TASKER, CHARCOTTE CON 2 NS, LOT 5 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	185	OCT 1955	16.8	18.6 19.2	FRESH --	16.8	3.7	7.6	0.4	DOMESTIC	0.0	6.1	HEAVY CLAY
												6.1	15.2	GRAVEL AND CLAY MIXED
												15.2	19.8	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	DRILLERS MATERIALS DESCRIPTION
2479	TASKER, THORNTON CON 2 NS, LOT 5 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	185	AUG 1962	76.2	12.8	FRESH	17.4	12.2	--	0.1	STOCK DOMESTIC	0.0 6.1 12.8 13.7	6.. 12.8 13.7 17.4	BROWN SANDY CLAY REDDISH BLUE CLAY BLUE CLAY WITH NARROW LAYERS OF SAND BLUE CLAY AND BOULDERS
2480	ARMSTRONG, MURRAY CON 2 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	189	OCT 1967	15.9	13.4	FRESH	13.4	3.7	11.6	0.5	DOMESTIC	0.0 12.8	12.8 13.4	BROWN CLAY COARSE GRAVEL
2489	LAWRENCE, W. CON 3 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	178	MAY 1954	15.9	17.4	FRESH	15.2	3.0	--	0.2	DOMESTIC	0.0 14.3	14.3 18.0	CLAY RED SHALE
2490	JARIUS BROS. CON 3 NS, LOT 2 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	183	DEC 1958	15.9	15.5	FRESH	14.0	4.0	22.9	0.1	DOMESTIC	0.0 0.6 9.4 12.5 14.0	0.6 9.4 12.5 14.0 22.9	LOAM BROWN CLAY BLUE CLAY, SOFT SOFT RED SHALE RED SHALE
2491	JARVIS, H. CON 3 NS, LOT 3 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	182	MAY 1960	15.2	19.5	FRESH	19.2	5.2	28.0	0.1	DOMESTIC	0.0 18.9	18.9 28.0	BROWN CLAY RED SHALE
2492	POLISH ASSOCIATION CON 3 NS, LOT 4 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	187	JUL 1952	15.2	19.5	FRESH	12.2	6.1	19.5	0.3	STOCK DOMESTIC	0.0 12.2	12.2 19.5	CLAY RED SHALE
2493	POLISH VILLAGE FARM CON 3 NS, LOT 4 (PREV. TRAFALGAR TWP.)	183	APR 1953	15.2	21.3	FRESH	15.2	6.1	[illegible]	0.4	STOCK DOMESTIC	0.0 15.2	15.2 22.3	CLAY AND SAND RED ROCK

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	TO (m)	MATERIALS DESCRIPTION
2494	SHERIN, J. CON 3 NS, LOT 4 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	182	JUN 1954	15.2	18.3	FRESH	18.8	3.0	--	0.8	DOMESTIC	0.0	16.8	CLAY
												16.8	18.6	RED SHALE
2495	LESLIE, J. CON 3 NS, LOT 4 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	182	AUG 1955	15.9	19.5	FRESH	18.3	3.7	18.9	0.4	DOMESTIC	0.0	4.6	CLAY
												4.6	12.2	SAND AND GRAVEL
												12.2	18.3	BLUE CLAY
												18.3	20.1	RED SHALE
2496	GILLIES, GRAHAM CON 3 NS, LOT 4 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	183	APR 1959	16.8	18.9	FRESH	14.6	6.7	15.2	0.5	DOMESTIC	0.0	14.3	CLAY
												14.3	19.8	RED SHALE ROCK
2497	SIKORSKI PARK CON 3 NS, LOT 4 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	188	JUN 1967	76.2	11.0	FRESH	11.8	7.3	10.4	0.1	COMM-ERCIAL	0.0	0.3	TOPSOIL
												0.3	2.7	BROWN CLAY
												2.7	5.8	HARDPAN
												5.8	6.4	BOULDERS
												6.4	10.7	BLUE CLAY
												10.7	11.0	GREY SHALE
2498	TRAFALGAR SCHOOL BRD. CON 3 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	188	JAN 1954	15.9	18.3	FRESH	18.3	7.3	--	0.2	PUBLIC SUPPLY	0.0	18.3	CLAY
2499	GREEN, DOUG CON 3 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	195	APR.1959	15.9	15.2	FRESH	13.7	7.2	10.7	0.3	DOMESTIC	0.0	0.6	TOPSOIL
												0.6	12.8	CLAY
												12.8	13.1	GREEN SHALE
												13.1	15.2	RED SHALE
2500	MILLIGAN, W.H., C. CON 3 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	189	MAY 1964	76.2	14.0	FRESH	14.3	7.6	--	0.1	DOMESTIC	0.0	3.0	TOP BROWN SOIL
												3.0	12.8	REDDISH CLAY
												12.8	14.0	RED SHALE, WATER COMES FROM THE BOTTOM

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	DRILLERS MATERIALS DESCRIPTION
2501	TERPSTRA, WILLIAM CON 3 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	188	JUL 1964	12.7	13.7	FRESH	12.8	4.6	12.2	0.6	DOMESTIC	0.0 5.5 11.0	5.5 11.0 13.7	BROWN CLAY SANDY CLAY RED SHALE
2502	STANBRA, J. CON 3 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	189	NOV 1967	76.2	6.4	FRESH	9.1	6.1	8.8	0.2	DOMESTIC	0.0 0.3 1.8 6.7	0.3 1.8 6.7 9.1	TOPSOIL BROWN SANDY CLAY HARD GREY CLAY GREY SAND
2504	MILTON MASIONIC LODGE CON 3 NS, LOT 8 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	192	APR 1956	15.9	13.7	FRESH	14.0	3.7	13.1	0.2	COMMER-CIAL	0.0 7.6	7.6 13.7	CLAY SAND AND FINE GRAVEL
2531	DR. BUCK, C. CON 4 NS, LOT 5 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	189	JUL 1959	15.9	16.8	FRESH	10.4	4.0	16.2	0.2	DOMESTIC	0.0 5.5 12.2 14.6	5.5 12.2 14.6 17.4	WELL DUG GREY CLAY BLUE CLAY RED SHALE
2782	JARVIS, H. CON 3 NS, LOT 2 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	182	OCT 1968	76.2	14.3	FRESH	--	4.6	--	--	DOMESTIC	0.0 3.0 13.7	3.0 13.7 14.3	TOP BROWN SOIL GREY CLAY SAND AND WATER
2792	MARTIN, C. CON 3 NS, LOT 7 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	190	NOV 1968	76.2	7.6	FRESH	11.3	1.2	--	--	DOMESTIC	0.0 0.6 7.3	0.6 7.3 11.0	TOPSOIL GREY AND BLUE CLAY BROWN CLAY WITH BOULDERS

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	DRILLERS TO (m)	DRILLERS MATERIALS DESCRIPTION
2809	SUKLJE, FRANK CON 2 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	183	APR 1968	76.2	14.6	SALTY	NA	--	--	0.0	DOMESTIC	0.0	0.3	TOPSOIL
												0.3	3.7	BROWN
												3.7	7.3	BLUE CLAY
												7.3	11.0	SOFT SHALE
												11.0	14.9	HARD SHALE
3181	GRANDIN, R. CON 2 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	185	JUN 1969	76.2	12.5	FRESH	13.1	3.0	--	--	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	3.7	HARD BROWN CLAY
												3.7	8.8	SOFT GREY CLAY
												8.8	11.6	HARD BROWN CLAY WITH STONES
												11.6	12.8	RED SHALE
3224	SMITH, D.B. CON 2 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	182	JUL 1969	76.2	15.2	FRESH	15.5	6.1	15.2	--	DOMESTIC	0.0	0.6	BROWN TOPSOIL
												0.6	4.6	BROWN CLAY, HARD
												4.6	9.4	BLUE CLAY HARD
												9.4	11.3	BROWN CLAY, STONES, HARD
												11.3	15.5	RED SHALE, HARD
3250	MARSHALL, JAMES CON 2 DSN, LOT 33 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	182	OCT 1969	76.2	11.0	FRESH	12.5	4.9	12.2	--	STOCK	0.0	0.3	BROWN TOPSOIL
												0.3	4.3	BROWN CLAY, HARD
												4.3	9.1	BLUE CLAY, HARD
												9.1	11.0	BROWN HARDPAN, STONES, HARD
												11.0	12.5	BROWN COARSE GRAVEL, PACKED
3258	LUEDERS, G. CON 7 NS, LOT 2 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	175	NOV 1969	76.2	4.6	FRESH	8.5	3.4	8.5	0.0	DOMESTIC	0.0	0.6	BLACK TOPSOIL
												0.6	3.7	BROWN CLAY, HARD
												3.7	4.6	GREY CLAY, STONES, HARD
												4.6	4.9	BROWN SAND, FINE GRAVEL, PACKED
												4.9	6.1	BROWN HARDPAN, STONES, HARD
												6.1	8.5	RED SHALE WITH GREEN LAYERS, HARD

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	DRILLERS TO (m)	DRILLERS MATERIALS DESCRIPTION
3260	BOYNE COMMUNITY CENTRE CON 3 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	189	NOV 1969	76.2	9.1	FRESH	11.6	6.1	11.6	--	PUBLIC SUPPLY	0.0	0.6	BLACK TOPSOIL
												0.6	4.9	BROWN CLAY, STONES, HARD
												4.9	6.7	GREY CLAY, STONES, HARD
												6.7	9.1	BROWN CLAY, SAND, STONES, HARD PACKED
												9.1	9.8	BROWN SAND, FINE GRAVEL, PACKED
												9.8	11.6	BROWN CLAY, STONES, HARD
3312	DENZIL, L. CON 1 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	187	FEB 1970	76.2	4.9 7.6	FRESH FRESH	12.5	3.0	12.2	--	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	4.9	BROWN CLAY, HARD
												4.9	6.4	GREY CLAY, STONES, HARD
												6.4	12.5	BROWN SAND, GRAVEL, SILT, HARDPACKED
3314	REYNOLDS, ROSS CON 2 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	183	DEC 1969	76.2	13.1	FRESH	13.7	3.7	13.7	--	DOMESTIC	0.0	0.3	BLACK TOPSOIL
												0.3	4.3	BROWN CLAY, STONES, HARD
												4.3	8.8	BLUE CLAY, STONES, HARD
												8.8	11.6	BROWN HARDPAN, STONES, HARD
												11.6	13.7	RED SHALE, HARD
3361	MARTIN, CHARLES CON 3 NS, LOT 7 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	190	APR 1970	76.2	13.4	FRESH	14.0	3.0	14.0	--	DOMESTIC	0.0	0.3	BLACK TOPSOIL
												0.3	4.9	BROWN CLAY, HARD
												4.9	6.4	GREY CLAY, STONES, HARD
												6.4	12.8	BROWN CLAY, STONES, HARD
												12.8	14.0	RED SHALE, HARD
3410	O.W.R.C. CON 3 NS, LOT 7 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	190	APR 1970	15.2	12.2	FRESH	21.3	3.4	17.1	1.1	NOT USED (OBSERV-ATION WELL)	0.0	1.1	BROWN TOPSOIL
												1.1	9.1	RED CLAY, STONES
												9.1	10.7	GREY GRAVEL, STONES AND SAND
												10.7	12.2	GREY GRAVEL, STONES AND SAND
												12.2	22.9	RED SHALE
3422	POLAKOW, S. CON 2 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	189	AUG 1970	15.9	19.5	FRESH	17.1	9.1	15.5	1.1	DOMESTIC	0.0	4.9	BROWN CLAY
												4.9	7.3	GREY CLAY
												7.3	12.2	GREY CLAY, GRAVELLY
												12.2	16.8	BROWN CLAY, GRAVELLY
												16.8	19.8	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	TO (m)	MATERIALS DESCRIPTION
3463	LEUDERS, G CON 1 NS, LOT 3 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	180	JUN 1970	76.2	11.3	FRESH	15.8	9.8	15.2	--	STOCK	0.0	0.3	BLACK TOPSOIL
												0.3	4.9	BROWN CLAY, HARD
												4.9	6.7	GREY CLAY, STONES, HARD
												6.7	11.6	BROWN CLAY, STONES, HARD
												11.6	15.8	RED SHALE, HARD
3467	FEIGMAN, LEONARD CON 1 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	185	JUN 1970	76.2	16.8	FRESH	17.1	--	16.5	0.2	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	4.6	BROWN CLAY, HARD
												4.6	7.6	BLUE CLAY, SOFT
												7.6	13.4	BROWN CLAY, STONES, HARD
												13.4	17.1	RED SHALE
3468	FEIGMAN, LEONARD CON 1 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	185	MAY 1970	76.2	16.5	FRESH	18.3	--	--	0.1	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	4.3	BROWN CLAY, HARD
												4.3	9.1	BLUE CLAY, SOFT
												9.1	11.6	BROWN CLAY, STONES, HARD
												11.6	18.3	RED SHALE, HARD
3525	POLISH VILLAGE FARM CON 3 NS, LOT 4 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	181	JUL 1970	76.2	6.4	FRESH	12.5	7.3	12.5	--	PUBLIC SUPPLY	0.0	0.3	BROWN TOPSOIL
												0.3	5.8	BROWN CLAY, STONES, HARD
												5.8	6.4	GREY CLAY, SILT, LAYERED
												6.4	9.1	GREY, SAND, GRAVEL
												9.1	10.7	RED CLAY, STONES, HARD
												10.7	12.5	RED SHALE, HARD
3535	MUM, HARRY CON 1 NS, LOT 1 TOWN OF OAKVILLE (PREV. TRAFALGAR TWP.)	184	AUG 1970	76.2	13.4	FRESH	14.0	6.1	14.0	--	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	4.3	BROWN CLAY, STONES, HARD
												4.3	9.8	BLUE CLAY, STONES, HARD
												9.8	12.5	BROWN CLAY, VERY HARD
												12.5	14.0	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	TO (m)	MATERIALS DESCRIPTION
3634	VANGEMERT, W.H. CON 2 DSN, LOT 27 TOWN OF OAKVILLE (PREV. TRAFALGAR TWP.)	160	OCT 1971	91.4	3.7 6.4 10.7	--	12.2	6.4	--	--	DOMESTIC	0.0 3.7 4.0 6.4 6.7 10.7 11.0 13.7	3.7 4.0 6.4 6.7 10.7 11.0 13.7	BROWN CLAY, BOULDERS, SOLID BROWN SAND SEAM RED SHALE AND CLAY GREY SAND SEAM RED SHALE AND CLAY, BOULDERS GREY GRAVEL SEAM RED CLAY, BOULDERS RED SOLID SHALE
4074	NURSE, WILLIAM CON 1 NS, LOT 3 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	181	FEB 1973	76.2	13.4	FRESH	14.0	1.8	14.0	0.3	DOMESTIC	0.0 0.3 3.7 4.9 7.6 9.4 12.2 13.4 13.7	0.3 3.7 4.9 7.6 9.4 12.2 13.4 13.7 14.0	BROWN TOPSOIL BROWN CLAY, STONES, SOFT PARTLY AND HARD PACKED GREY CLAY, STONES, PACKED BROWN CLAY, RED CLAY, SAND LAYER, PACKED GREY CLAY, HARD PACKED BROWN CLAY, STONES, HARD PACKED BLUE CLAY, SOFT GREY GRAVEL, COARSE SAND BROWN CLAY, STONES, HARD
4113	TASKER, WARREN CON 2 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	184	OCT 1972	76.2	16.2	FRESH	17.4	6.1	--	--	DOMESTIC	0.0 0.3 8.8 9.1 11.3 14.3	0.3 8.8 9.1 11.3 14.3 17.4	BROWN TOPSOIL BLUE CLAY, SOFT BROWN COARSE SAND RED CLAY, STONES, HARD RED CLAY, BOULDERS, HARD PACKED RED SHALE, GREEN SHALE, HARD
4123	PULES, W CON 1 NS, LOT 1 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	185	MAR 1972	76.2	11.6 15.2	FRESH	16.0	3.7	11.0	0.9	DOMESTIC	0.0 0.3 4.6 9.4 11.6	0.3 4.6 9.4 11.6 16.0	BROWN TOPSOIL BROWN CLAY, HARD PACKED BLUE CLAY RED CLAY, STONES RED SHALE, GREEN SHALE, HARD

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	DRILLERS TO (m)	DRILLERS MATERIALS DESCRIPTION
4261	INGLE, J CON 2 DSN, LOT 27 TOWN OF OAKVILLE (PREV. TRAFALGAR TWP.)	163	JUL 1973	15.2	15.8	FRESH	7.3	3.7	13.7	0.2	DOMESTIC	0.0	4.0	BROWN CLAY
												4.0	6.7	BLUE AND GREY CLAY
												6.7	16.8	RED SHALE ROCK
4458	DORRGELLO, BILL CON 1 NS, LOT 2 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	186	AUG 1973	76.2	15.5	FRESH	16.8	0.9	5.5	0.5	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	4.3	BROWN CLAY, HARD
												4.3	6.1	GREY CLAY
												6.1	11.0	RED CLAY, GREY CLAY, SAND, HARD
												11.0	14.6	RED CLAY, HARD
												14.6	16.8	RED SHALE, GREEN SHALE, HARD
4587	JOHNSON, BOB CON 7 NS, LOT 3 TOWN OF MILTON (PREV. NELSON TWP.)	180	JUL 1974	91.4	2.4 6.1	FRESH FRESH	6.1	--	--	--	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	1.2	BROWN CLAY, STONES
												1.2	3.7	GREY CLAY
												3.7	9.1	RED SHALE
5001	HUETTEN, HENRY CON 1 NS, LOT 2 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	185	DEC 1976	76.2	15.2 16.5	FRESH FRESH	16.5	3.0	12.8	0.1	DOMESTIC STOCK	0.0	0.3	BROWN TOPSOIL
												0.3	3.4	BROWN CLAY, SOFT BUT PACKED
												3.4	8.8	BLUE CLAY, SOFT
												8.8	12.2	BROWN RED CLAY, STONES, BOULDERS, VERY HARD
												12.2	12.8	RED CLAY, PACKED
												12.8	16.5	RED SHALE, GREEN SHALE, HARD
5149	SNOW, EARL CON 7 NS, LOT 4 TOWN OF MILTON (PREV. NELSON TWP.)	181	OCT 1977	76.2	7.9 9.8 11.6	FRESH	12.2	5.1	11.9	1.1	DOMESTIC	0.0	0.3	UNKNOWN
												0.3	1.2	BROWN CLAY
												1.2	6.1	LIGHT GREY CLAY, BROWN SILT
												6.1	7.9	BROWN CLAY, STONES
												7.9	11.9	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS FROM (m)	TO (m)	MATERIALS DESCRIPTION
5151	G AND F HEREFORD CON 3 NS, LOT 4 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	181	OCT 1977	76.2	14.6 18.3	FRESH FRESH	17.1	2.7	16.2	1.1	STOCK	0.0 0.3 3.7 5.2 6.4 13.4 14.6 18.0	0.3 3.7 5.2 6.4 13.4 14.6 18.0 18.6	BROWN TOPSOIL BROWN CLAY, PACKED GREY CLAY, BOULDERS, PACKED BROWN CLAY, SILT, SAND, PACKED GREY CLAY, BROWN CLAY STONES BROWN SAND, CLAY, (CAVING IN) SOFT BROWN CLAY, STONES, BOULDERS RED SHALE
5657	NOFLAC, F CON 2 DSN, LOT 31 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	181	JUL 1980	76.2	15.2	FRESH	14.6	6.1	10.4	1.0	DOMESTIC	0.0 0.3 3.7 7.6 14.0	0.3 3.7 7.6 14.0 15.4	BROWN TOPSOIL BROWN CLAY BLUE CLAY, SOFT BROWN CLAY, GREY CLAY, STONES, RED CLAY RED SHALE, GREEN SHALE
5663	POMPA, B CON 1 NS, LOT 3 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	180	JUN 1980	76.2	10.7	FRESH	11.6	1.2	4.6	0.8	DOMESTIC	0.0 0.3 5.5 6.1 10.7	0.3 5.5 6.1 10.7 11.6	BROWN TOPSOIL BROWN CLAY, PACKED BLUE CLAY, SOFT RED CLAY, STONES, PACKED BROWN SAND, STONES, LOOSE
5689	OPSTEEN, F CON 4 NS, LOT 3 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	185	DEC 1980	76.2	9.1 13.4	FRESH FRESH	--	7.6	--	--	DOMESTIC	0.0 0.3 4.6 6.1 8.2 12.8	0.3 4.6 6.1 8.2 12.8 14.3	BROWN TOPSOIL BROWN CLAY BROWN SAND, CLAY, STONES REDDISH CLAY, PLENTY OF STONES, HARD GREY CLAY, BROWN & GREY SAND, STONES RED SHALE, GREEN SHALE
5823	VERRES, G CON 1 NS, LOT 7 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	193	OCT 1975	76.2	0.3 4.9	FRESH FRESH	4.9	3.0	6.1	1.1	DOMESTIC	0.0 0.3 1.8	0.3 1.8 6.1	BROWN TOPSOIL BROWN CLAY, STONES, PACKED RED SHALE, GREEN SHALE, SOFTER AT 4.6 THEN VERY HARD

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-1N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	DRILLERS MATERIALS DESCRIPTION FROM (m)	TO (m)	
5025	AGOSINO, J CON 1 NS, LOT 6 TOWN OF MILTON (PREV. TRAFALGAR TWP.)	180	JUL 1972	76.2	10.4	FRESH	9.8	3.4	10.4	1.1	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	9.1	BROWN CLAY, RED CLAY, SOME GREY, SOME SANDY LAYERS BUT MAINLY STONES AND BOULDERS
												9.1	10.4	RED SHALE, GREEN SHALE, VERY HARD

8.2 SUMMARY OF SITE INTERVIEW (WALK AND TALK) DATA

Water use data from Ecologistics Limited's field interview (Walk and Talk) forms is presented in Figure 8 (in map pocket). Water use data were collected from on site or adjacent properties. A copy of the water resources form is attached at the end of this section.

Water use data are augmented with information collected by Gartner Lee Associates Limited staff during discussions with local interest groups and individuals.

The results of water well surveys completed by Gartner Lee Associates Limited in 1976 and by Morrison Beatty Limited in 1984 are also incorporated in the summary of site interview data.

Deeper drilled wells are considered to terminate in bedrock where supporting evidence is available.

Although most of the information was provided in Imperial units, it has been converted to metric units for uniformity with the remainder of the report.

Interview numbers are related to identifications assigned by Ecologistics Limited during the collection of these data.

Copies of the interview forms are on file.

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site PI-1N Sheet 1 of 16

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
1	Jesse and Clarence McCann	6	3NS	758	✓			Drilled Well (No MOE Record) - 30 years old - Used for house - Water quality hard
		Town of Milton (formerly Trafalgar Twp.)						
2	Ms. Jesse Goddard	7	2NS	627		✓		Dug/Bored Well (No MOE Record) - Not used
		Town of Milton (formerly Trafalgar Twp.)						
3	Ms. Marjorie Jarvis	4	4NS	121-2		✓	✓	Dug/Bored Well (No MOE Record) - Approx. 7.6-9.1 m (25-30 ft) deep, supplies livestock - Old well Cistern used for house Bottled water for drinking Pond on property (Same as No. 4)
		Town of Milton (formerly Trafalgar Twp.)						

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
4	Mr. Gordon Rayner	4 Town of Milton (formerly Trafalgar Twp.)	4 NS	418 G	✓			Drilled Well (No MOE Record) - 27.4 m (90 ft) deep - Water quality hard, sulphurous, salty - Well not used Spring used for house Pond and Creek water for livestock (same as No. 3)
5	Mr. Roman Lash	5 Town of Milton (formerly Trafalgar Twp.)	3NS	46-2		7		Dug/Bored Wells (No MOE Records) - 6 wells are capped - One well used for barn and house - 2.1 m (7 ft) deep, never runs dry Dug pond on property
6	Mr. and Mrs. Opstein	4 Town of Milton (formerly Trafalgar Twp.)	3NS	265-2	✓	3		Drilled Well (MOE record 2492) - 18.3 m (60 ft.) deep - Used for livestock - Poor water quality Dug/Bored Wells (MOE Wells 2497 and 3525, no MOE record for 3rd well) - 2 wells used for house - 8.2 and 13.1 m (27 and 43 ft.) deep (wells 2497 and 3525 respectively) - 3rd well supplies livestock, 18.3 m (60 ft.) deep.

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
7	Mr. and Mrs. M. Dolby	5 Town of Milton (formerly Trafalgar Twp.)	3NS	27-1		✓	✓	Dug/Bored Well (No MOE Record) - 8.5 m (28 ft) deep - Used for drinking - Water quality hard, trace of sulphur Cistern used for laundry and toilet
8	Mr. and Mrs. S.E. Dolby	6 Town of Milton (formerly Trafalgar Twp)	3NS	414G		✓		Dug/Bored Well (No MOE Record) - 7.0 m (23 ft) deep - Used for house and business (wash trucks) - Excellent drinking water, is hard - Well seldom goes dry
9	Mr. P. Szkilniak (for Mr. A. Brkic)	6 Town of Milton (formerly Trafalgar Twp.)	2NS	35-2		(✓)		Dug/Bored Well (May Be Drilled) (No MOE Record) - Water is bitter, not potable - Location uncertain Pond on property

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
10	Ms. Audrey Curtis	5	2NS	39-2		2		Dug/Bored Well (No MOE Record) - Used for house - Water is hard - Well slow to refill Dug/Bored Well (No MOE record) - supplies livestock
		Town of Milton (formerly Trafalgar Twp.)						
11	Mr. Brian Smith	5	2NS	44-2				Pond on property Buy one load of water per year Suspects 2 Wells on Property - No information on wells Pond on Property
		Town of Milton (formerly Trafalgar Twp.)						
12	Mr. and Mrs. Joe Rada	5	2NS	12-1	✓			Drilled Well (MOE Well 2478) - Used for house and livestock - Water quality hard, some iron content
		Town of Milton (formerly Trafalgar Twp.)						
13	Vitetta and Ms. Rita Leone	4	3NS	80-1a	✓			Drilled Well (MOE Well 2493) - 27.4 m (90 ft) deep - Used for house - Water quality very hard
		Town of Milton (formerly Trafalgar Twp.)						

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site PI-1N Sheet 5 of 16

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
14	Mr. Ken Wettlaufer	4	2NS	293				No Water Use Information
		Town of Milton (formerly Trafalgar Twp.)						
15	Mr. De Paoli	4	2NS	14-2				No Water Use Information
		Town of Milton (fomerly Traflagar Twp.)						
16	Mr. and Mrs. F. Vertulia	4	3NS	124-1	✓			Drilled Well (MOE Well 2494) - 18.3 m (60 ft) deep - Used for house - Water is hard
		Town of Milton (formerly Traflagar Twp.)						
17	Mr. and Mrs. Tomosky	4	2NS	60-2	✓	5		Drilled Well (MOE Well 2477) - supplies household and livestoc Dug/Bored Wells (No MOE Records) - 4 dug wells not used - 1 dug well over 6.1 m (20 ft) deep - Used for house - Good water quality Two ponds on property
		Town of Milton (formerly Trafalgar Twp.)						

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
18	Mr. and Mrs. G. Gillies	4	3NS	217-2	✓	✓		Drilled Well (MOE Well 2496) - 18.3 m (60 ft) deep - Used for house and livestock - Good water quality but hard Dug/Bored Well (MOE Well 5151) - 18.3 m (60 ft) deep - supplies house Pond on property
		Town of Milton (formerly Trafalgar Twp.)						
19	Mr. and Mrs. A. Hall	4	3NS	86-1a	✓			Drilled Well (MOE Well 2495) - Used for house - Water quality very hard, not good drinking water
		Town of Milton (formerly Trafalgar Twp.)						
20	Gentex Pharmaceuticals Inc.	5	1NS	37-2				No Water Use Information
		Town of Milton (formerly Trafalgar Twp.)						

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site PI-1N Sheet 7 of 16

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
21	Mr. and Mrs. W.T. Martin	4	2 NS	21-2	✓			Drilled Well (MOE Well 2476) - 21.9 m (72 ft) deep - Water level in well 7.6 m (25 ft) - Used for house - Water quality good, hard
		Town fo Milton (formerly Trafalgar Twp.)						
22	Mr. Frank Jelinek	3	2 NS	57-1		✓		Dug/Bored Well (MOE Well 2475) - 18.3 m (60 ft) deep - Used for house - Water quality good, hard
		Town of Milton (formerly Trafalgar Twp.)						
23	Mr. Peter Lambrick	2	2 NS	292				Pond on Property No Water Use Information
		Town of Milton (formerly Trafalgar Twp.)						
24	Mr. Ian Waid	5	1 NS	448-G		✓		Dug/Bored Well (No MOE Record) - Used for house - Water quality excellent, hard Pond near barn
		Town of Milton (formerly Trafalgar Twp.)						

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
25	Mr. Bill Bousfield	4	2NS	126-2				No Water Use on Property
		Town of Milton (formerly Trafalgar Twp.)						
26	Mr. and Mrs. K. Chaput	3	1 NS	15-2		✓		Dug/Bored Well (MOE Well 4074) - 0.8 m (30 inch) diameter - Used for house - Water quality good, slightly hard Pond on property
		Town of Milton (formerly Trafalgar Twp.)						
27	Mr. Walter Chlon	3	1 NS	238-2		✓		Dug/Bored Well (No MOE Record) - 12.8 m (42 ft) deep - Recently dug, supplies house - Water quality hard Pond on property
		Town of Milton (formerly Trafalgar Twp.)						
28	Mr. and Mrs. B. Pompa	3	1 NS	51-2		✓		Dug/Bored Well (MOE Well 5663) 11.6 m (38 ft) deep - Used for house - Water quality hard Two ponds on property
		Town of Milton (formerly Trafalgar Twp.)						

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site PI-1N Sheet 9 of 16

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
29	Mr. and Mrs. Clare Ford	3	2NS	22-1		✓	✓	Dug/Bored Well (No MOE Record) - 5.2 m (17 ft) deep - Used for house - Goes dry once every two years - Water quality good, hard Cistern used for laundry and toilet
		Town of Milton (formerly Trafalgar Twp.)						
30	Mr. Lloyd Moore	3	1NS	781		✓		Dug/Bored Well (No MOE Record) - 15.8 m (52 ft) deep - Used for house - Water quality seems good
		Town of Milton (formerly Trafalgar Twp.)						
31	Mr. Ken Wettlaufer	2	2NS	293				No Water Use Information
		Town of Milton (formerly Trafalgar Twp.)						
32	Ms. Beverley Ketelaurs	3	1NS	222-1	✓	✓		Dug/Bored Well (No MOE record) - 15.2-16.8 m (50-55 ft.) deep - Used for house - periodically goes dry Drilled Well (No MOE Record) - 21.3 m (70 ft) deep - Used for house, also bottled water for drinking
		Town of Milton (formerly Trafalgar Twp.)						

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
33	Mr. and Mrs. A. Mishos	2 Town of Milton (formerly Trafalgar Twp.)	1NS	18-1A		✓		Dug/Bored well (no MOE record) - 16.5 m (54 ft) deep - used for house and livestock - water quality hard - well completed in 1975 Pond on property
34	Mr. & Mrs.M. A. DaSilva	4 Town of Milton (formerly Trafalgar Twp.)	1NS	467-G		✓		Dug/Bored well (no MOE record) - 15.5 m (51 ft) deep - used for house - water quality, hard - has dried up twice in 10 years
35	Mr. F. Van Wassenaer	3 Town of Milton (formerly Trafalgar Twp.)	1NS	272		2		2 Dug/Bored Well (MOE well 3563 and no MOE Record) - overall 17.1 m (56 ft) deep - used for house and livestock - water quality good Two ponds on property
36	Mr. & Mrs. G. Vanderheyden	2 Town of Milton (formerly Trafalgar Twp.)	1NS	440-G	✓			Drilled well (MOE well 2456) - 6.1 m (20 ft) deep - used for house - water quality good hard
37	Mr. H. Gowland	2 Town of Milton (formerly Trafalgar Twp.)	1NS	45-2	✓	✓	✓	Dug/Bored well (no MOE record) - 8.5 m (28 ft) deep - used for house - water quality good, hard Drilled well (no MOE record) - 7.0 m (23 ft) deep - used for livestock - water quality good, hard Cistern used for livestock

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
38	Mr. George Marshall	4 Town of (formerly	1NS Milton Trafalgar Twp.)	19-2		✓	✓	Dug/Bored well (no MOE record) - 9.1 m (30 ft) deep - used for house and livestock - water quality very good - well has never gone dry Cistern used for house
39	Mrs. Joanne Templeman	4 Town of (formerly	1 NS Milton Trafalgar Twp.)	459-G	✓	✓		Drilled well (no MOE record) - 12.6 m (41.5 ft) - water quality good, hard Dug/Bored well (no MOE record) - used for drinking and cooking - water quality good, a little hard
40	Mr. & Mrs. Frank Hagemans	6 Town of (formerly	3NS Milton Trafalgar Twp.)	419-G	✓			Drilled Well (MOE Well 2499) - 13.7 m (45 ft.) deep - used for house - water quality good but hard
41	M. E. Jarvis	2 Town of (formerly	2NS Milton Trafalgar Twp.)			✓		Dug/Bored well (no MOE record) - Morrison Beatty Ltd. Well Survey
42	no name provided	2 Town of (formerly	3NS Milton Trafalgar Twp.)		✓			Drilled well (no MOE record) - Morrison Beatty Ltd. well survey
43	Matheson	3 Town of (formerly	3NS Milton Trafalgar Twp.)		✓			Drilled well (no MOE record) - Morrison Beatty Ltd. well survey

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
44	E. Douglas	5 Town of Milton (formerly Trafalgar Twp.)	3 NS			✓		Dug/Bored well (no MOE record) - Morrison Beatty Ltd.well survey
45	Stout	6 Town of Milton (Formerly Trafalgar Twp.)	3 NS			✓		Dug/Bored well (no MOE record) - Morrison Beatty Ltd.well survey
46	Gartner Lee Associates Ltd. field observation	7 Town of Milton (formerly Trafalgar Twp.)	2 NS			2		Dug/Bored wells (no MOE record) - not used
47	Gartner Lee Associates Ltd. field observation	4 Town of Milton (formerly Trafalgar Twp.)	1 NS			✓		Dug/Bored well (no MOE record) - abandoned
48	Hedges	5 Town of Milton (formerly Trafalgar Twp.)	2 NS			2		Dug/Bored wells - 1st well MOE well 2479 - 2nd well no MOE record - Morrison Beatty Ltd.well survey
49	Mr. J. Strutt	7 Town of Milton (formerly Trafalgar Twp.)	1 NS	244-2	✓	2		Drilled Well (no MOE record) - 35.5 m (110 ft)deep - water quality sulphurous, salty not used Dug/Bored wells (no MOE record) - one is 13.4 m (44 ft) deep domestic use - one not used

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site P1-1N Sheet 13 of 16

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
50	Mr. J. Reid (tenant)	7 Town of Milton (formerly Trafalgar Twp.)	7 NS	516		✓		Dug/Bored well (no MOE record) - water quality sulphurous - not used (same as No. 66)
51	Mr. N. Mogil (owner)	7 Town of Milton (formerly Trafalgar Twp.)	7 NS	54-2				- drinking water not particularly good - No further information supplied (same as No. 50)
52	Mr. J. De Angeles	6 Town of Milton (formerly Trafalgar Twp.)	7 NS	37-1A	✓	✓	✓	Drilled well (no MOE record) - 13.7 m (45 ft) deep Supplies household Dug/Bored well (no MOE record) - used for livestock - 9.1 m (30 ft.) deep (GLAL field information) Cistern used to supply house as backup to drilled well (GLAL field information) Pond on property
53	Mr. J. McLaren (same as 52)	6 Town of Milton (formerly Trafalgar Twp.)	7 NS	764	✓		✓	Drilled well (no MOE record) - goes dry in summer, supplies house Cistern on property (new) Pond on property
54	Mr. A. Palermo	6	1 NS	123-1	✓		✓	Drilled well (no MOE record) - 18.3 m (60 ft.) deep supplies household and livestock Cistern domestic use Pond used for livestock

Table 5 SUMMARY OF SITE INTERVIEW DATA

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
55	Palermo	6 Town of Milton (formerly Trafalgar Twp.)	1NS			2		Dug/Bored wells (no MOE record) - located on property Morrison Beatty Ltd. Well Survey
56	Mr. J. Snyder	5 Town of Milton (formerly Trafalgar Twp.)	1NS	760				No wells on property
57	Ms. J. Peric	5 Town of Milton (formerly Nelson Twp.)	7NS	43-2				No wells on property
58	Mr. Earl Snow	4 Town of Milton (formerly Nelson Twp.)	7NS	143-2	✓	(✓)		Drilled well (no MOE record) - 23.5 m (77 ft) deep, drilled in 1923 - used for house and livestock - water quality hard, iron Wells-unknown type (no MOE record) a number of old (abandoned) wells on property
59	Mr. & Mrs. G. Love	4 Town of Milton (formerly Nelson Twp.)	7NS	100-2		✓	✓	Dug/Bored well (MOE well 5149) - 12.2 m (40 ft) deep, completed in 1977 - used for house - overflows in the spring Cistern used for house - water soft, not always nice to drink
60	Mr. Stewart Scott	4 & 5 Town of Milton (formerly Nelson Twp.)	7NS	609				No water use reported Pond on property
61	Robert F. Kowal Instruments Ltd.	6 Town of Milton (formerly Nelson Twp.)	7NS	204				No water use reported

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site PI-1N Sheet 15 of 16

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
62	Sanford	3 Town of Milton (formerly Nelson Twp.)	7NS			(✓)		well of unknown type (GLAL, 1980)
63	Scott	2 Town of Milton (formerly Trafalgar Twp.)	2NS			(✓)		well of unknown type (GLAL, 1980)
64	N/A	1 Town of Milton (formerly Trafalgar Twp.)	3NS			(✓)		well of unknown type (GLAL, 1980)
65	Crew	3 Town of Milton (formerly Trafalgar Twp.)	2NS			(✓)		well of unknown type (GLAL, 1980)
66	Mr. P. Easterbrook (tenant - resident)	7 Town of Milton (formerly Nelson Twp.)	7NS	GLAL FIELD VISIT	✓	✓	✓	Dug/Bored Well (no MOE record) - 10.7 m (35 ft) deep - livestock use - water has sulphur smell Drilled Well (no MOE record) - abandoned, plugged Cistern in basement Buy water for drinking

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site PI-1N Sheet 16 of 16

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
67	Ms. M. D. Hall	3	7NS	486-G	✓			Drilled well (no MOE record) - supplies house - 25.9 m (85 ft) deep, 15.2 cm (6 in) diameter casing Pond on property - good for cattle
68	Mr. H. K. Jarvis	2	3	Z-87		✓		Dug/bored well (MOE well 2782) - supplies household - 14.6 m (48 ft.) deep - water quality hard - never goes dry

WATER RESOURCES FORM

Interview Identification Number: _____

PHYSICAL RESOURCES - WATER

We are interested in the water used on this property: where it comes from, its quality, and how much you use.

1. What is this household's source of supply for domestic water? (e.g., drinking, laundry, toilet)

drilled water	☐	Locate on map with symbol Dr-H
dug wells	☐	Locate on map with symbol Du-H
stream water	☐	Locate on map with symbol *SW-H
cistern	☐	Locate on map with symbol *C-H
bottled water	☐	
municipal main	☐	
other, specify		_____

2. What is the water supply for the livestock and irrigation on this property?

drilled wells	☐	Locate on map with symbol Dr-A
dug wells	☐	Locate on map with symbol Du-A
streams or dams	☐	Locate on map with symbol *SW-A
cisterns	☐	
municipal main	☐	
other (e.g., ponds)		_____

3. Are there any streams or ponds on your property?

streams	Yes ☐	No ☐
ponds	Yes ☐	No ☐

4. What can you tell us about the quality of the water

a) you use or drink? (hard, soft, sulphurous, iron, salty, etc.) _____
_____
_____

b) in the streams or ponds? _____
_____
_____

5. Do the wells, cisterns or streams that you use for water supply ever go dry? If so, how often? _____
_____
_____
_____

Interview Identification Number: _____

6. Can you tell us anything about the construction of the wells? (e.g., when they were drilled, depth, type of pump, name of the driller) _____

7. Has any portion of your property been filled or excavated? If so, please show where on the map. (Locate on map with symbol EV.)

8. Do you know where there are any gas or oil wells on your property or the property you farm - in use or abandoned? . Please show their locations on the map with the symbol GW.

9. Please tell us about any problems with flooding in the creeks and streams on your property. Please show locations of the flooded areas on the map. (Locate with symbol FA.) _____

8.3 BOREHOLE LOGS

8.3.1 GARTNER LEE ASSOCIATES LIMITED BOREHOLE LOGS, 1984
- Site PI-1N
- Site LF-4N

8.3.2 GARTNER LEE ASSOCIATES LIMITED BOREHOLE LOGS AND TEST PIT LOGS, 1976-1979

8.3.3 MORRISON BEATTY LIMITED BOREHOLE LOGS, 1984
- Site PI-1N
- Site LF-4N

8.3.4 HYDROLOGY CONSULTANTS BOREHOLE LOGS, 1984
- Site PI-1N
- Site LF-4N

8.3.5 MINISTRY OF TRANSPORTATION AND COMMUNICATIONS BOREHOLE LOGS, 1969

8.3.1 BOREHOLE LOGS - GARTNER LEE ASSOCIATES LIMITED - 1984

Borehole locations are shown in Figure 4 (in map pocket).

Borehole logs are based on field notes which have been verified by the project geologist following re-examination of the samples.

Continuous samples were obtained by advancing a large split tube (8.9 cm x 152 cm) through the hollow stem augers.

Standard penetration tests were performed at 1.5 m intervals and water contents were measured in samples taken from the 'nose-piece' of the standard split spoon sampler.

Textural descriptions are provided for each geologic unit and each deposit is named (in brackets) to indicate its origin.

All material descriptions are based on visual hand sample examination and no laboratory grain size analyses were performed. Textural descriptions are provided under 'Particle Size Classification System' in the Glossary of Selected Terms, Section 8.5.

Borehole elevations are estimated from the 1 10:000 scale base map contours. All elevations are abovew sea level (ASL) and are estimated to the nearest metre.

The term pebble has been used to describe gravel sized rock particles within a fine grained matrix.

GEOTECHNICAL NOTES AND ABBREVIATIONS

Standard Penetration Resistance 'N' - The number of blows required to advance a standard split spoon sampler 30 cm into the subsoil, driven by means of a 63.5 kg hammer falling freely a distance of 75 cm.

The consistency of cohesive soils and the relative density or denseness of cohesionless soils are described as follows:

Consistency	'N' Blows per 0.3 m	Denseness	'N' Blows per 0.3 m
Very soft	0-2	Very Loose	0-4
Soft	2-4	Loose	4-10
Firm	4-8	Compact	10-30
Stiff	8-15	Dense	30-50
Very Stiff	15-30	Very Dense	> 50
Hard	> 30		

ABBREVIATIONS

WTPL - Wetter than Plastic Limit

DTPL - Drier than Plastic Limit

APL - About Plastic Limit

Wp - Plastic Limit

WL - Liquid Limit

SS - Split Spoon Sample

T - Split Tube Sample

SITE PI-1N

BOREHOLE NO. GL 84-1(1N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** November 7, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger,Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 181 m (approximately) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
0-3	TOPSOIL: very dark greyish brown clayey silt topsoil, occasional root								
	SILT TO CLAYEY SILT TILL: brown to dark greyish brown silt to clayey silt till, heavily weathered to 1.4 m, discoloured fractures common to 4.2 m, numerous shale pebbles, colour change brown to grey at ±4.1 m, hard to very stiff (Halton Till)			1	SS	45	10		
				2	SS	32	12		
				3	SS	16	14		
5.7	SANDY SILT TILL: brown sandy silt till, occasional silt lamina to 2 cm in upper 0.5 m, numerous shale pebbles, decreasing pebble and sand content in lower 0.5 m, saturated, compact (Lower Till)			4	SS	12	10		
				5	SS	21	11		
8.7	SILT: grey silt to clayey silt, massive to laminated, very stiff			6	SS	24	16		
9.4	SAND: grey silty fine to coarse sand, laminated with occasional silt or clay lamina to 1 cm, saturated			7	SS	50	9		
10.7	SILT TO CLAYEY SILT TILL: brown to reddish brown silt to clayey silt till, massive, numerous shale fragments, increasing pebble content with depth, hard (Lower Till)			8	SS	*	11	*75/0.15m	
				9	SS	*	9	*82/0.15m	
15.2	SILTY FINE TO COARSE SAND: brown to reddish grey silt,fine to coarse sand, laminated, with occasional clayey silt interbed to 10 cm in upper 1 m, very loose to very dense, saturated			10	SS	54	23		
17.0				11	SS	0	16	spoon sank	
	SILT TILL: grey to reddish grey clayey silt to sandy silt till, variable, increasing sand and pebble content with depth, two silt interbeds, to 0.4mbetween 18.2 and 18.8 m, saturated, very dense (Lower Till)			12	SS	111	11		
				13	SS	118	14		
21.7				14	SS	60	12		
	SILTSTONE TO SHALE: reddish brown to light grey-green calcareous siltstone with shale interbeds, approximately 2/3 siltstone, 1/3 shale interbeds. (Queenston Formation)			15	SS	N/A	N/A	no sample	
25.6				16	SS	*	8	*80/0.15m	

Borehole terminated at 25.6 m in shale

Gartner Lee Associates Limited

BOREHOLE NO. GL 84-2 (1N)

PROJECT NAME Phase 4A Drilling & Sampling

CLIENT Ontario Waste Management Corporation **DATE** November 17, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 180 m. (approximately) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m	WATER CONTENT % / COMMENTS
0.2	FILL: dark brown sand and gravel							20 40 60	10 20 30 Wp Wl
0.4	TOPSOIL: very dark greyish brown clayey silt topsoil			1	SS	23	17		
	SILT TO CLAYEY SILT TILL: brown silty to clayey silt till, heavily weathered to ±1.5 m, numerous fractures to ±3.0 m, occasional discoloured fracture to ±3.8 m, increasing sand content in till below 5.6 m, sand laminae to 2 cm at 6.6 and 7.2 m, very stiff to hard (Halton Till)			2	SS	45	12		
				3	SS	42	11		
				4	SS	43	9		
8.5				5	SS	47	10		
	SANDY TO CLAYEY SILT TILL: brown sandy to clayey silt till, variable, with silt, sand and gravel zones and beds, silty sandy fine gravel bed 9.7 to 9.8 m, massive to indistinctly laminated, saturated, very dense (Lower Till)			6	SS	95	10		
				7	SS	86	7		
				8	SS	53	9		
				9	SS	53	20		
	- gravelly coarse to medium sand bed (14.9 to 15.1 m)			10	SS	114	8		
				11	SS	103	8		
17.6									
18.7	INTERBEDDED SILT AND TILL: brown interbedded laminated clayey silt and clayey silt till hard (Lower Till)			12	SS	80	21		
	SILTY FINE SAND TO SILTY SANDY GRAVEL: reddish brown silty fine sand to silty sandy gravel (to 6 cm), laminated, saturated, very dense			13	SS	*	N/A	*50/0.01m no sample	
20.9									
	SILT TILL: reddish brown silt to sandy silt till, variable, with inclusions of laminated clayey silt in upper 1 m, gravelly zones, numerous shale fragments, saturated, very dense (Lower Till)			14	SS	*	17	*49/0.07m	
				15	SS	*	N/A	*75/0.02m no sample	
23.8	SHALE AND SILTSTONE: reddish brown shale with calcareous siltstone zones, weathered zones, shale is fine bedded, occasional grey-green zone (Queenston Formation)								

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BOREHOLE NO. GL 84-2(1N) (Continued)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** November 17, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Augers, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 180 m (approximately) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
27.5	SHALE AND SILTSTONE: (continued)								
	Borehole terminated at 27.5 m in shale								

Gartner Lee Associates Limited

BOREHOLE NO. GL 84-3 (1N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** November 5, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Augers, Continuous Sampling **GEOLOGIST** A.B./A.C.

GROUND ELEVATION 186 m (approximately) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: dark brown silt topsoil, numerous roots and bits of organic matter								
	SILT TILL: brown silt till, with clay, numerous shale fragments, heavily weathered to ±1.5 m, discoloured fractures common to 3.6 m, colour change at 5.5 m, fracture with grey carbonate stain at 5.4 m, two beds silty fine sand (5 cm, 14 cm thick) between 5.8 and 6.1 m, sharp lower boundary, hard (Halton Till)			1	SS	37	12		
				2	SS	60	12		
				3	SS	50	11		
6.9				4	SS	32	10		
	SILTY SAND TILL: brown silty sand till, variable, sandy zones, sand laminae and sand beds to 13 cm are common, massive to indistinctly laminated, very sandy 11.0 to 11.5 m with sand beds to 13 cm thick, gradational to bedrock in basal 0.5 m, saturated, very dense (Lower Till)			5	SS	*	8	*61/0.15m →	
				6	SS	*	9	*80/0.13m →	
				7	SS	99	7	→	
11.9				8	SS	*	N/A	*75/0.05m →	
	SILTSTONE AND SHALE: reddish brown siltstone and shale, interbedded, siltstone is calcareous and hard, shale is interbedded and softer, occasional grey-green coloured zone, siltstone/shale interbeds average ±10 cm in thickness (Queenston Formation)								
15.0	Borehole terminated at 15.0 m in shale								

BOREHOLE NO. GL 84-4 (1N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** November 2, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Augers, Continuous Sampling **GEOLOGIST** A.B./A.C.

GROUND ELEVATION 183 m (approximately) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
0.3	TOPSOIL: very dark greyish brown silt to clayey silt topsoil, with roots								
	SILT TO CLAYEY SILT TILL: dark greyish brown silt to clayey silt till, weathered to ±1.5 m, fractures common to 3.0 m, colour change at ±3.8 m, occasional discoloured fracture to 4.6 m, discoloured zone in till 4.6 to 4.8 m, increase in clay content with depth, hard to very stiff (Halton Till)			1	SS	33	16		
				2	SS	70	14		
				3	SS	16	16		
5.6									
	SILT TO CLAYEY SILT TILL: dark grey silt to clayey silt till, occasional lamina to 1 cm thick of silt or fine sand, yellowish brown discoloured lamina at 5.8 m, very stiff to hard (Lower Till)			4	SS	15	12		
7.9				5	SS	49	11		
8.4	SILTY SAND: dark grey laminated silt to silty fine to medium sand, saturated, sharp upper boundary			6	SS	*	9	*55/0.15m	
	SILT TO CLAYEY SILT TILL: brown silt to clayey silt till, variable with silty and sandy zones to ±10 cm thick, occasional silt to fine sand lamina to 2 cm, hard (Lower Till)			7	SS	114	8		
13.0				8	SS	*	5	*75/0.13m	
13.8	CLAYEY SILT TO SILTY VERY FINE SAND: reddish brown clayey silt to silty very fine sand, very dense, saturated			9	SS	*	18	*80/0.15m	
	SILT TO CLAYEY SILT TILL: reddish brown silt to clayey silt till, variable with sandy to gravelly zones to 20 cm thick, increasing gravel content with depth, abundant shale, silty sandy fine gravel beds 15.4 to 15.6 m, 15.7 to 15.9 m, 17.3 to 17.4 m, 18.2 to 18.4 m, gradational lower contact to bedrock, hard (Lower Till)			10	SS	*	8	*78/0.15 m	
				11	SS	*	8	*81/0.15m	
18.9				12	SS	*	8	*85/0.15m	
20.1	SILTSTONE TO SHALE: reddish brown interbedded siltstone and shale, siltstone is calcareous and harder, shale softer and partly weathered, beds to 10 cm thick. (Queenston Formation)								
	Borehole terminated at 20.1 m in shale.								

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BOREHOLE NO. GL 84-5 (1N)

PROJECT NAME Phase 4a Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** November 6, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Augers, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 186 m (approximately) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: brown clayey silt topsoil, numerous roots and organic matter								
0.9	CLAYEY SILT: brown clayey silt, occasional pebble, heavily weathered, numerous stained fractures			1	SS	30	14		
				2	SS	42	14		
				3	SS	17	13		
	SILT TO CLAYEY SILT TILL: dark greyish brown to reddish brown silt to clayey silt till, numerous shale fragments, numerous fractures to 4.0 m, occasional clay, silt or fine sand laminae to 5 cm thick below 8.5 m, becoming variable below ±9.0 m, becoming laminated ± low 10.5 m, very stiff to hard (Halton Till)			4	SS	N/A	9	no "N" value	
				5	SS	48	9		
				6	SS	67	16		
				7	SS	101	7	→	
11.6	SANDY SILT TO SILTY SAND TILL: brown sandy silt to silty sand till, variable, with silt and sand laminae zones and interbeds to (0.7 m thick) till dominant overall but sand dominant over smaller intervals, saturated, very dense (Lower Till)			8	SS	*	9	*78/0.15m →	
				9	SS	*	15	*75/0.08m →	
14.7	FINE TO COARSE SAND: very fine to coarse sand, laminated, occasional silty zone or clayey silt lamina, includes till interbeds to 0.6 m thick gradational to units above and below, very dense, saturated			10	SS	*	17	*64/0.15m →	
				11	SS	*	37	*69/0.15m →	
				12	SS	*	14	*105/0.15m →	
				13	SS	*	16	*75/0.08m →	
20.9	SANDY SILT TO SILTY SAND TILL: dark grey to reddish brown silty sand till, occasional silt to fine sand lamina, interbeds (to 30 cm thick) and zones, increasing sand and gravel content with depth, abundant reddish brown shale, gradational contact with bedrock, saturated, very dense (Lower Till)			14	SS	*	13	*100/0.15m →	
				15	SS	*	7	*75/0.05m →	
				16	SS	*	7	*80/0.05m →	

BOREHOLE NO. GL 84-5 (1N) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** November 6, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Augers, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 186 m (approximately) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % (10 20 30) Wp — Wl / COMMENTS
	SILTY SAND TILL (continued) (Lower Till)			17	SS	*	8	*80/0.05m →	•
26.4									
	SILTSTONE AND SHALE: reddish brown calcareous siltstone and interbedded shale, occasional grey-green zones, fractured. (Queenston Formation)								
27.7	Borehole terminated at 27.7 m in shale								

SITE LF-4N

BOREHOLE NO. GL 84-2 (4N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE November 13/84

BOREHOLE TYPE 108mm I.D.Hollow Stem Augers, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 184 m (approximately) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: very dark grayish brown clayey silt topsoil, occasional organics								
1.3	SILTY CLAY: dark grayish brown silty clay, occasional small (<1 cm) pebble, carbonate concretions, silt lamina to 0.5 cm between 0.7 and 0.8 m			1	SS	62	11		
	SILT TO CLAYEY SILT TILL: brown silt to clayey silt till, fractures common to ±3.0 m, discoloured fracture 3.4 m, very stiff to hard (Halton Till)			2	SS	42	12		
				3	SS	21	11		
				4	SS	15	13		
	— 2 cm thick lamina of medium sand at 8.0 m			5	SS	16	13		
	— increasing silt and pebble content below ±10 m			6	SS	28	11		
				7	SS	26	10		
				8	SS	26	11		
	— grading to laminated silty clay to silt with occasional till-like layer to 2 cm thick, occasional small (<1 cm) pebble (±13.7 to 15.9 m)			9	SS	24	12		
				10	SS	21	10		
	— return to silt to clayey silt till at ±15.9 m — 7 cm thick layer fine sand at 16.0 m.			11	SS	45	9		
18.8	— interbedded silty clay to clayey silt and clayey silt till below ±18.0 m			12	SS	35	25		
	SILT TO SANDY SILT TILL: brown silt to sandy silt till, variable, with sand interbeds to 30 cm and sandy zones, saturated, very dense (Lower Till)			13	SS	103	8		
21.9				14	SS	120	8		
	LAMINATED CLAYEY SILT: dark grey laminated clayey silt, with pebbley and till-like zones, hard			15	SS	88	22		
				16	SS	72	20		

Gartner Lee Associates Limited

BOREHOLE NO. LF 84-2 (4N) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation — DATE November 13/84

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, Continuous Sampling — GEOLOGIST AB/AC

GROUND ELEVATION 184 m (approximately) — PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
25.8	LAMINATED CLAYEY SILT: (continued)			17	SS	73	10		
26.5	SANDY SILT TILL: brown sandy silt till, saturated (Lower Till)								
27.8	SILTY SAND: grey silty medium to coarse sand, with gravel, very dense, saturated			18	SS	80	23		
	CLAYEY SILT AND CLAYEY SILT TILL: brown to dark grey clayey silt and clayey silt till, interbedded and gradational in approximately equal proportions, occasional silt lamina to 2 mm, silt layer 31.4 to 31.5 m, hard (Lower Till)			19	SS	88	12		
				20	SS	80	13		
31.8					+T	NA	17		
	SILTY SANDY GRAVEL TO SILTY FINE SAND: grey silty sandy gravel to silty fine sand, variable, till-like in places, saturated				+T	NA	14		
					+T	NA	10		
37.1									
	SHALE: reddish brown shale, weathered with occasional siltstone zone, occasional grey-green band (Queenston Formation)								
38.9	Borehole terminated at 38.9 m in shale								
	+ moisture contents taken from (T) split tube samples								
50									

Gartner Lee Associates Limited

BOREHOLE NO GL 84-3 (4N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE November 16/84

BOREHOLE TYPE 108 mm I.D.Hollow Stem Augers,Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 188 m (approximately) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: very dark greyish brown silt topsoil, occasional root or straw								
1.0	SILTY CLAY TO CLAYEY SILT: yellowish brown mottled, weathered numerous fractures, rusty 1 cm thick silt lamina at 0.4 m			1	SS	46	21		
	CLAYEY SILT TO SILT TILL: dark greyish brown clayey silt to silt till, numerous shale pebbles, fractures common to ±3.0 m, inclusions of silt till to 4 cm 2.9 to 3.1 m, rusty coloured lamina of fine sand (0.5 cm thick) at 5.4 m, occasional indistinct laminations below 5.5 m, increasing silt, sand and pebble content below ±7.0 m, gradational lower contact, hard to very stiff (Halton Till)			2	SS	33	19		
				3	SS	18	20		
				4	SS	16	12		
8.3				5	SS	15	11		
	SILT TILL: brown silt till, variable with sandy and clayey zones, occasional silty fine sand lamina and inclusions to 0.5 cm, 9.7 to 10.1 m silty sandy fine gravel, saturated, very dense (Lower Till)			6	SS	57	9		
11.0				7	SS	NA	NA	No recovery	
	CLAYEY SILT TO CLAYEY SILT TILL: brown clayey silt to clayey silt till, interbedded and gradational, occasional pebble, silty sandy medium gravel 15.0 to 15.1 m, hard (Lower Till)			8	SS	140	21		
15.1				9	SS	124	12		
				10	SS	100	8		
18.3	SILTSTONE TO SHALE: reddish brown siltstone to shale, calcareous, with harder zones, occasional grey-green zones, weathered (Queenston Formation)								
	Borehole terminated at 18.3 m in shale								
25									

Gartner Lee Associates Limited

BOREHOLE NO. GL 84-4 (4N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE November 15/84

BOREHOLE TYPE 108 mm I.D.Hollow Stem Augers, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 184 m (approximately) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: very dark greyish brown clayey silt topsoil, occasional root								
0.9	CLAYEY SILT TO SILTY CLAY: brown, mottled, heavily weathered, carbonate concretions			1	SS	39	14		
	CLAYEY SILT TO SILT TILL: brown clayey silt to silt till, fractures common to ±3.9m, indistinct banding 6.6 to 6.8 m, indistinct banding to laminations 11.3 to 13.4 m, silty sandy fine gravel 11.8 to 12.0 m indistict banding below ±17.0 m, decreasing pebble content and increasing clay below 18.7 m, laminated silt 19.3 to 19.4 m, hard to stiff (Halton Till)			2	SS	44	11		
				3	SS	23	13		
				4	SS	26	14		
				5	SS	22	10		
				6	SS	27	11		
				7	SS	25	11		
				8	SS	20	12		
				9	SS	25	13		
				10	SS	10	15		
				11	SS	12	12		
				12	SS	15	15		
19.4									
	COARSE SAND TO FINE GRAVEL: coarse sand to fine gravel, saturated, compact			13	SS	16	15		
20.9								No sample	
	SILT TILL: reddish brown silt till, variable, silty zone 23.4 to 23.6 m, numerous shale fragments, saturated, very dense (Lower Till)			14	SS	*	8	* 65/0.1 m	
23.7									
	CLAYEY SILT: dark greyish brown clayey silt, laminated, reddish brown colour banding (continued)			15	SS	*	8	* 72/0.2 m	

Gartner Lee Associates Limited

BOREHOLE NO GL 84-4 (4N) (cont'd)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation DATE November 18/84

BOREHOLE TYPE 108 mm I.D.Hollow Stem Augers, Continuous Sampling GEOLOGIST AB/AC

GROUND ELEVATION 184 m (approximately) PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp, Wl)
	CLAYEY SILT: (continued), occasional small (<1 cm) pebble, three stony bands 2 to 3 cm thick between 29.3 and 29.5 m, hard			16	SS	*	15	* 130/0.2 m	
				17	SS	*	17	* 135/0.2 m	
29.5				18	SS	*	17	* 117/0.2 m	
	SANDY SILT TILL: reddish brown sandy silt till, bouldery, possible gravel inclusions, very dense (Lower Till)			19	N/A	N/A	N/A		
	NOTE: poor sample recovery 28.5 to 40.0m			20	SS	89	6		
35.0									
	GRAVELLY MEDIUM TO COARSE SAND: reddish brown medium to coarse sand, very dense, saturated			21	SS	*	10	* 60/0.1 m	
37.1				22	SS	*	NA	* 70/0.1 m	
	CLAYEY SILT TILL: reddish brown clayey silt till, hard (Lower Till)			23	SS	*	NA	* 90/0.15 m	
40.0									
	SHALE TO SILTSTONE: reddish brown shale to siltstone, siltstone occurs as zones in shale ±1/3 volume, occasional grey-green coloured zones in rock, weathered and fractured (Queenston Formation)								
42.4									
	Borehole terminated at 42.4 m in shale								

8.3.2 GARTNER LEE ASSOCIATES LIMITED BOREHOLE LOGS AND TEST PIT LOGS, 1976-1979.

SITE LF-4N and vicinity
(GLAL 1980)

Borehole locations are shown in Figure 4.

Vertical scales are variable. Depths are in feet.

GLAL BOREHOLE LOGS, 1976-1979

BOREHOLE NO. GL-3

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 7/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 612.05 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
		Clayey Silt Till:						
		Grey brown clayey silt till, shale fragments, hard DTPL	1	SS	40			
			2	SS	27			
		Becomes grey silty clay till after 20', WTPL					▲ ▲	←installed April 1977
			3	SS	9		●	
			3A	SS	5			
28.0'		Sandy Silt Till						
		Brown sandy silt till, sand lenses, saturated, very dense, seepage seams	4	SS	50/5			
			5	SS	50/4			
			6	SS	50/2			
			7	SS	50/3			
67.0'		Shale Till Complex:						
69.1		Red Shaley Silt till	8	SS	50/2		●	
		Hole terminated at 69.1 on Queenston Shale						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-4

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71
CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 12/10/76
BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL
ELEVATION 601.93 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	BLOWS/FT.	% WATER	GROUND WATER	REMARKS
		Clayey Silt Till Grey brown clayey silt till, Queenston shale fragments	1	SS	24			
			2	SS	24			
			3	SS	18		▲	▲ installed April 1977
			4	SS	15		▲	
			5	SS	18		●	
			6	SS	14			
			7	SS	14			
			8	SS	50/2			
84.0'			9	SS	50/3			
		Sandy Silt Till: Brown sandy silt till,						
90.0'								

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-4 (cont'd)

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 12/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION _____ — TECHNOLOGIST _____

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
99.0'								
		Clayey Silt: Well-sorted grey lacustrine clayey silt.	10	SS	81			
		Sand and Gravel: Brown sand and gravel, saturated.	11	SS	130/6			
			12	AS				
		Hole terminated at 120.0' in sand and gravel						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-5

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71
CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 22/10/76
BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL
ELEVATION 603.03 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till Grey brown clayey silt till, becomes silty clay till locally	1	SS	52			
			2	SS	67			
		becomes grey after 20' ±	3	SS	9		▲	
			4	SS	48			
			5	SS	64			
			6	SS	50/3			
			7	SS	50/3			
68.0'		Sandy Silt Till: Brown sandy silt till, sand layers, seepage seams					●	
80'0'		Hole terminated at 80.0'.						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-6

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 12/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 609.75 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till:						
		Grey brown clayey silt till, shale fragments	1	SS	60			
			2	SS	50		▲	
			3	SS	26			
			4	SS	70		●	
36.0		Sandy Silt Till: Brown sandy silt till, sand seepage seams, saturated.	5	SS	50/2			
			6	SS	50/15			
			7	SS	50/2			
			8	SS	50/2			
			9	SS	50/2			
88.0		Shale tillcomplex	10	SS	50/2		●	

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-7

PROJECT NAME: Proposed Halton Landfill Site "F" — PROJECT NO. 76-71
CLIENT: Region of Halton c/o M.M. Dillon Limited — DATE: 13/10/76
BOREHOLE TYPE: 3¼" Hollow Stem Flight Augers — GEOLOGIST: EGA/RL
ELEVATION: 613.65 — TECHNOLOGIST:

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till						
		Grey brown clayey silt till, shale fragments	1	SS	47			
			2	SS	52			
			3	SS	43		▲	
24.0		Sandy Silt Till: Brown sandy silt till, saturated, very dense, sand seepage seams	4	SS	50/3"			
			5	SS	50/2"		●	
			6	SS	50/2"			
			7	SS	50/2"			
			8	SS	50/2"			
79.0		Shale Till Complex:	9	SS	50/2"			
			10	SS	50/2"		●	
83.0		Hole terminated at 83.0 on shale						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-8

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 19/10/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RI

ELEVATION 623.59 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till:						
		Brown clayey silt till, shale fragments	1	SS	67			
			2	SS	50/4			
18.0'		Sandy Silt Till: Brown sandy silt till, sand seams, saturated.	3	SS	50/6		▲	
26.0'		Shale Till Complex: Red shaley silt till, many angular Queenston shale fragments.	4	SS	50/6		●	
38.0'		Borehole terminated at 38.0' on Queenston Shale						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-12

PROJECT NAME: Proposed Halton Landfill Site "F" — PROJECT NO. 76-71
CLIENT: Region of Halton c/o M.M. Dillon Limited — DATE: 8/10/76
BOREHOLE TYPE: 3¼" Hollow Stem Flight Augers — GEOLOGIST: EGA/RL
ELEVATION: 616.75 — TECHNOLOGIST:

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till Brown clayey silt till	1	SS	53		▲	
			2	SS	50/4			
14.0'		Sandy Silt Till: Brown sandy silt till, saturated, sand seams	3	SS	50/2			
			4	SS	50/3			
32.0'		Shale Till Complex: Red shaley silt till	5	SS	50/2		●	
43.0'		Hole terminated at 43.0' in shale till complex						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-14

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 26/10/76

BOREHOLE TYPE 601.32 — GEOLOGIST EGA/RL

ELEVATION — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till						
		Grey brown clayey silt till, shale gragments	1	SS	57			
			2	SS	82			
			3	SS	18		▲	▲ installed April 1977.
			4	SS	53		▲	
			5	SS	60			
			6	SS	52			
			7	SS	50/6			
68.0'		Sandy Silt Till: Brown sandy silt till, sand seams, saturated						
			8	SS	50/5			
90.0'		Hole terminated at 90.5'.	9	SS	50/5		●	

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-16

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 28/10/76 - 1/11/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 603.36 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till:						
		Brown clayey silt till, shale fragments	1	SS	37			
			2	SS	50/6			
			3	SS	21		▲	
		becomes grey after 35'	4	SS	25			
			5	SS	51			
			6	SS	50/6		●	
60.0'								
		Hole terminated at 60.0' in till.						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. GL-17

PROJECT NAME Proposed Halton Landfill Site "F" — PROJECT NO. 76-71

CLIENT Region of Halton c/o M.M. Dillon Limited — DATE 1/11/76

BOREHOLE TYPE 3¼" Hollow Stem Flight Augers — GEOLOGIST EGA/RL

ELEVATION 604.70 — TECHNOLOGIST

DEPTH ELEV.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
		Clayey Silt Till: Brown clayey silt till, shale fragments	1	SS	65			
			2	SS	41			
			3	SS	48			
			4	SS	50/4		▲	
34.0'		Sandy Silt Till: Grey brown sandy silt till, seepage seams saturated	5	SS	50/2			
44.0'		Shale Till Complex Red shaley silt till	6	SS	50/2		●	
53.0'		Hole terminated at 53.0' in shale till complex.						

● Piezometer ▲ Standpipe

Gartner Lee Associates Limited

BOREHOLE NO. 1-1

PROJECT NAME HALTON SITE 'F' CONTINUED — PROJECT NO. 79-112
CLIENT M. M. DILLON LIMITED — DATE SEPT. 26, 1979
BOREHOLE TYPE 3¼" I.D. Hollow Stem Augers — GEOLOGIST E.G.A.
ELEVATION 100.6 — TECHNOLOGIST I.I.

DEPTH ELEV. Ft.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
0'6"		TOPSOIL						
		GLACIAL TILL brown clayey silt till with minor shale fragments - dense to compact, wet.	1	SS	28	15		
			2	SS	41	11		
			3	SS	44	13		
			4	SS	48	11		saturated
			5	SS	27	12		
			6	SS	17	12	▲	
			7	SS	11	14		
			8	SS	5	18		
			9	SS	12	19		
24'0"		FINE SAND dark grey silty fine sand, saturated					●	
25'6"			10	SS	56	8		
			11	SS	66	3		
		GLACIAL TILL grey brown clayey silt till with very minor fine sand lenses from 27'6"± to 30'0"± very dense - saturated	12	SS	61	5		
			13	SS	52	10		
			14	SS	57	10		
			15	SS	41	13		
			16	SS	32	11	●	
41'6"		Borehole terminated at 41'6" in clayey silt till						

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. 12

PROJECT NAME HALTON SITE 'F' CONTINUED — PROJECT NO. 79-112
CLIENT M. M. DILLON LIMITED — DATE Sept. 27, 1979
BOREHOLE TYPE 3½" I.D. Hollow Stem Augers — GEOLOGIST E.G.A.
ELEVATION 93.7 — TECHNOLOGIST L.L.

DEPTH ELEV. Ft.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
0'6"		TOPSOIL						
		GLACIAL TILL medium brown clayey silt till with mixed shale fragments compact to dense - wet	1	SS	19	13		
			2	SS	30	13		saturated
			3	SS	33	12		
			4	SS	31	12		
			5	SS	26	13		
			6	SS	7	14		
		change to grey	7	SS	11	12	▲	
			8	SS	19	10		
			9	SS	21	10		
			10	SS	26	10		
			11	SS	27	9		
			12	SS	31	11		
			13	SS	30	11		
			14	SS	19	11		
			15	SS	23	11		
			16	SS	24	12	●	
41'6"		Borehole terminated at 41'6" in clayey silt till						

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

BOREHOLE NO. L-3

PROJECT NAME HALTON SITE 'F' CONTINUED — PROJECT NO. 79-112

CLIENT M. M. DILLON LIMITED — DATE Sept. 27, 1979

BOREHOLE TYPE 3¼" I.D. Hollow Stem Augers — GEOLOGIST E.G.A.

ELEVATION 99.5 — TECHNOLOGIST L.L.

DEPTH ELEV. Ft.	STRATIGRAPHY	DESCRIPTION	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS/FT.	SAMPLE % WATER	GROUND WATER	REMARKS
0'7"		TOPSOIL						
		GLACIAL TILL medium brown clayey silt till with minor fractures, and with mixed shale fragments - compact - wet	1	SS	39	10		
			2	SS	35	11		saturated
			3	SS	40	11		
			4	SS	42	13		
			5	SS	24	11		
		change to grey	6	SS	13	13		
			7	SS	20	10	▲	
			8	SS	15	12		
			9	SS	14	14		
			10	SS	13	19		
			11	SS	26	10		
			12	SS	35	10		
			13	SS	42	10		
			14	SS	35	12		
			15	SS	26	10		
41'6"			16	SS	24	17	●	
		Borehole terminated at 41'6" in clayey silt till						

● Piezometer Tip ▲ Standpipe Tip

Gartner Lee Associates Limited

GLAL TEST PIT LOGS, 1976-1979

April 19, 1977

TEST PIT LOGS
HALTON SITE 'F'

Test Pit # 1

Pit was excavated to expose the standpipes GL-14-11, with one wall of the pit intersecting the borehole.

0 - 1' Black loamy topsoil.

1 - 4.5' Very fractured mottled gray and brown till. Fractures oxidized, irregular, with poorly defined horizontal habit. Fracture seepage from 3 to 4.5'; blocks appear to be under saturation. Friable texture.

4.5 - 10' Massive brown-gray clayey silt till with minor fracturing decreasing with depth. Pebble content increases with depth with some boulders > 1' below 9'. No seepage. Friable, increasingly blocky with depth.

Hole terminated at 10'.

NOTES: The standpipe borehole was full of water over the entire exposed length, indicating that fracture flow in the upper 4.5' of the till is entering the borehole below the upper bentonite seal. This may give rise to erroneous water table readings in many of the standpipes. Water in the fractured till

represents recent spring infiltration. This water is transient and may perch above the true water table, dissipating through evapo-transpiration and interflow before equilibrating with the water table.

Test Pit # 2

Pit excavated 10' north of a stock pond located approximately 300' north of GL-14.

0 - 1.5'	Black to brown friable clay loam topsoil.
1.5 - 6'	Very fractured clayey silt till, mottled by oxidation haloes around fractures. Fractures irregular but preferentially near horizontal. Till is predominantly gray to 3', increasingly brown to 6'. Considerable fracture seepage over the entire unit was accomplanied by slumping of the pit walls.
6 - 10'	Very compact red-brown clayey silt till with low pebble content and occasional boulder. No significant fracturing visible. Till has blocky habit, breaking into platy fragments. No seepage even after one hour, and no slumping was observed.

Hole terminated at 10'.

Test Pit #3

Located at the intersection of the Kowal, Mogil and Freeman properties, on a height of land.

0 - 1.5'	Black to brown (with depth) friable clay loam topsoil.
1.5 - 3.5'	Mottled gray-brown fractured till, quite red below 3' due to high Queenston shale content. Fractures oxidized and irregular, with horizontal habit. No seepage.
3.5 - 6'	Transition zone from fractured to massive till. Increasing red shale content with depth. By 5' fractures are widely spaced, and till breaks into blocks several inches in dimension. Secondary gypsum was observed in several fractures from 4 to 6'. Its presence indicates discharge conditions and approximately defines the water table.
6 - 9'	Very compact red clayey silt till with many highly weathered Queenston shale fragments and blocks. No visible fracturing or seepage.

Hole terminated at 9'.

8.3.3 BOREHOLE LOGS - MORRISON BEATTY LIMITED

- Covering letter
- Site PI-1N
- Site LF-4N

Borehole locations are shown in Figure 4 (in map pocket).

Continuous samples were obtained by advancing a large split tube (8.9 cm x 15.2 cm) through the hollow stem augers.

Ground elevations at the boreholes are estimated from the contours on the 1:10 000 scale base maps and are rounded to the nearest metre in Figure 4.

SITE PI-1N

morrison beatty limited
consulting engineers and hydrogeologists
4500 dixie road, unit 12a, mississauga, ontario L4W 1V7 (416-624-9308)

November 9, 1984

Mr. Ken Goff
Gartner Lee Associates Limited
Toronto-Buttonville Airport
Markham, Ontario
L3P 3J9

Dear Sir:

re: Hydrogeologic Studies
of the
Milton Sites for OWMC
Our File No. 413-841

This letter confirms our meeting today at 10:00 a.m. to discuss our work at OWMC Sites No. PI-1N and LF-4N.

We have enclosed preliminary copies of the borehole logs at the four locations we tested at each site. Maps showing the test locations and private well locations are also included.

The well logs are abbreviated, since detailed examination of the borehole samples has not been completed. They show the significant stratigraphic units only.

Yours very truly,
MORRISON BEATTY LIMITED

Brian W. Beatty, P.Eng.

NJR/dc

morrison beatty limited
consulting engineers and hydrogeologists

1N-OW1

CLIENT _____ FILE NO 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site PI-1N)

GEOLOGIST / ENGINEER TH DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL	3	10	
	6	20	
	9	30	
	12	40	
STRATIFIED DRIFT	15	50	
TILL	18	60	
SHALE	21	70	
	24	80	
	27	90	
	30	100	
	33	110	
	36	120	
	39	130	
	40		

morrison beatty limited
consulting engineers and hydrogeologists

1N-OW2

CLIENT _____ FILE NO 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site PI-1N)

GEOLOGIST / ENGINEER TH DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL: clayey silt	3	10	
	6	20	
TILL: silty sand	9	30	
	12	40	
SHALE	15	50	
	18	60	
	21	70	
	24	80	
	27	90	
	30	100	
	33	110	
	36	120	
	39	130	
	40		

morrison beatty limited
consulting engineers and hydrogeologists

1N-OW3

CLIENT

FILE NO 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site PI-1N)

GEOLOGIST / ENGINEER 1H DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL	3	10	
	6	20	
	9	30	
	12	40	
	15	50	
STRATIFIED DRIFT	18	60	
TILL	21	70	
STRATIFIED DRIFT	24	80	
SHALE	27	90	
	30	100	
	33	110	
	36	120	
	39	130	
	40		

morrison beatty limited
consulting engineers and hydrogeologists

1N-OW4

CLIENT

FILE NO 413-841

PROJECT Hydrogeologic Study

LOCATION Proposed OWMC Sites (Site PI-1N)

GEOLOGIST / ENGINEER TH

DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL	3	10	
	6	20	
	9	30	
STRATIFIED DRIFT			
TILL	12	40	
	15	50	
STRATIFIED DRIFT	18	60	
SHALE	21	70	
	24	80	
	27	90	
	30	100	
	33	110	
	36	120	
	39	130	
	40		

SITE LF-4N

morrison beatty limited
consulting engineers and hydrogeologists

4N-OW3

CLIENT _____ FILE NO 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site LF-4N)

GEOLOGIST/ENGINEER TH DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL: with some silt and clay layers	3	10	
	6	20	
	9	30	
	12	40	
STRATIFIED DRIFT	15	50	
	18	60	
TILL: with some silt and clay layers	21	70	
	24	80	
	27	90	
STRATIFIED DRIFT	30	100	
SHALE	33	110	
	36	120	
	39	130	
	40		

morrison beatty limited
consulting engineers and hydrogeologists

4N-OW4

CLIENT _____ FILE NO 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site LF-4N)

GEOLOGIST / ENGINEER TH DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL	3	10	
	6	20	
	9	30	
	12	40	
STRATIFIED DRIFT	15	50	
TILL	18	60	
STRATIFIED DRIFT	21	70	
TILL	24	80	
	27	90	
STRATIFIED DRIFT			
TILL	30	100	
STRATIFIED DRIFT	33	110	
	36	120	
	39	130	
	40		

8.3.4 BOREHOLE LOGS - HYDROLOGY CONSULTANTS - 1984

- Site PI-1N
- Site LF-4N

Borehole locations are shown in Figure 4 (in map pocket).

Sample intervals are indicated on the attached logs.

Elevations provided on the borehole logs are rounded to the nearest metre in Figure 4.

SITE PI-1N

Borehole Log

Trow Ltd

Auger Sample ⊠ | Natural Moisture x
SPT (N) Value ○ ○ ▨ | Plastic and Liquid Limit ⊢—○
Dynamic Cone Test —— | Undrained Triaxial at Overburden Pressure 0 / 15 ⊕ 5 / 10 ; % Strain at Failure
Shelby Tube ● ● ■
Field Vane Test +s
Lab Vane Test t | Penetrometer ▲

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg No. Page 1
Borehole No. D1
Project No. T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m	N Value (ASTM) D1586-CSA A119.1) 20 40 60 80 / Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN/m³
		CLAYEY SILT TILL WITH SOME SAND: reddish brown, mottled, green staining, dry, hard	186.47	0			
		Changes to occasional grey silt layers, hard		1			
		No distinct break between weathered and unweathered till		2			
		SANDY SILT TILL WITH SOME CLAY: Reddish brown, mottled, green shale layers and fragments, dry-moist, very dense	181.4	3			
		Changes to greyish brown		4			
		SANDY SILT TILL: Greyish brown, fissile, shale fragments, dry, very dense	178.3	5			
		CLAYEY SILT TILL: Reddish brown, red & grey contorted laminations, pockets of moist silt, may be reworked lacustrine material.	177.1	6			
				7			
				8			
				9			
				10			

TLRD1-0

Borehole Log

Trow Ltd

Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Field Vane Test
Lab Vane Test

Natural Moisture
Plastic and Liquid Limit
Undrained Triaxial at Overburden Pressure
% Strain at Failure
Penetrometer

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg. No Page 2
Borehole No. D1
Project No. T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m	N Value (ASTM) D1586-CSA A119.1 / Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight	Natural Unit Weight kN/m³
		SANDY SILT TILL: Brown wet, hard, shale fragments, may be reworked lacustrine material	176.4	10			
				11			
				12	90/6"		
				13			
		Changes to reddish brown, saturated, some clay found					
				14	90/6"		
		Interpreted to be bedrock	171.9	15			
					100/3"		
		END OF BOREHOLE	171.0	16			
				17			
				18			
				19			
				20			

0-1011

Borehole Log

Trow Ltd

Auger Sample ⊠ | Natural Moisture ⊗
SPT (N) Value ○ ○ ⊠ | Plastic and Liquid Limit ⊢—○
Dynamic Cone Test ——— | Undrained Triaxial at Overburden Pressure, % Strain at Failure 0, 5, 10, 15
Shelby Tube ● ● ■ | Penetrometer ▲
Field Vane Test +s
Lab Vane Test t

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg. No. Page 1
Borehole No D2
Project No T 3780-HY
Hole location and datum see drawing No. 1

GWL	Symbol	Soil Description	ELEV m	Depth m	N Value (ASTM D1586-CSA A119.1) 20 40 60 80 / Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN/m³
			184.18	0			
		CLAYEY SILT TILL: Reddish brown, mottled, weathered, fragments of green and grey shale, dry, hard		1			
				2			
		Layers and fragments of green and grey shale, mottled, moist, weathering and fractures observed to 3.0 m		3			
				4			
		Changes to greyish brown, traces of fine sand, wet, hard	179.1	5			
		SANDY SILT TILL WITH SOME CLAY: Dark brown to reddish brown, shale fragments, saturated, very hard		6			
				7			
		Changes to greyish brown, wet, hard		8			
		Changes to reddish brown, fissle, dry, very hard		9	⊕ 100/6"		
				10			

TL80HO

Borehole Log

Trow Ltd

Auger Sample ⊠
SPT (N) Value ○ ○ ⊠
Dynamic Cone Test ——
Shelby Tube ● ● ■
Field Vane Test +s
Lab Vane Test t

Natural Moisture w
Plastic and Liquid Limit ⊢—o
Undrained Triaxial at Overburden Pressure ⊕ 0 15 5 10
% Strain at Failure
Penetrometer ▲

Project HALTON ENVIRONMENTAL
ASSESSMENT
Hole location and datum see drawing No. 1

Dwg No Page 2
Borehole No. D2
Project No. T 3780-HY

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m	N Value (ASTM) D1586-CSA A119.1) 20 40 60 80 Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN/m³
		Very wet, hard	174.1	10			
				11		○	
		Saturated		12		○ 50/6"	
				13			
				14		⊙ 110/6"	
		SHALE/TILL COMPLEX: Interbedded reddish brown silt and shale, dry, very hard	170.0	15			
			168.8			⊙ 100/5"	
		END OF BOREHOLE		16			
				17			
				18			
				19			
				20			

ILHDRO

Borehole Log

Trow Ltd

Auger Sample ⊠ | Natural Moisture w
SPT (N) Value ○ ○ ▨ | Plastic and Liquid Limit ⊢—○
Dynamic Cone Test —— | Undrained Triaxial at Overburden Pressure 0 / 15 ⊕ 5 / 10
Shelby Tube ● ● ■ | % Strain at Failure
Field Vane Test +s | Penetrometer ▲
Lab Vane Test t

Project HALTON ENVIRONMENTAL ASSESSMENT
Hole location and datum see drawing No. 1

Dwg. No. Page 1
Borehole No. D3
Project No. T 3780-HY

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH m
		CLAYEY SILT TILL: Reddish brown, mottled, weathered fragments of grey and green shale, moist to dry, hard	184.3	0
		Weathered and mottled to 3 m		1
				2
				3
				4
		Changes to greyish brown, moist, very stiff		5
			178.3	6
		SANDY SILT TILL: Brown, very hard, shale fragments, moist		7
		Traces of medium sand, mottled, wet, dense		8
		Changes to greyish brown, shale zones, moist to wet		9
			174.7	10
		SANDY SILT TILL: Greyish brown, fissile, pieces of shale, moist, hard		

N Value (ASTM D1586-CSA A119.1) 20 40 60 80
Shear Strength MPa

Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30

Natural Unit Weight kN/m³

TLH01-0

Borehole Log

Trow Ltd

Auger Sample ⊠ | Natural Moisture ×
SPT (N Value ○ ○ ◪ | Plastic and Liquid Limit ⊢—○
Dynamic Cone Test ——— | Undrained Triaxial at Overburden Pressure % Strain at Failure 0 5 10 15
Shelby Tube ● ● ■ | Penetrometer ▲
Field Vane Test +s
Lab Vane Test t

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg. No. Page 2
Borehole No. D3
Project No. T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH m	N Value (ASTM D1586-CSA A119.1) 20 40 60 80 Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN/m³
			174.3	10			
					⊖85/6"		
				11			
		Changes to red, dry					
				12			
					⊖ 130/3"		
				13			
		Changes to reddish brown, moist					
					⊖130/3"		
				14			
				15			
			168.9		⊖100/4"		
		Borehole terminated in red shale		16			
				17			
				18			
				19			
				20			

TL0470

Borehole Log

Auger Sample ⊠ | Natural Moisture ×
SPT (N) Value ○ ○ ▨ | Plastic and Liquid Limit ⊢—o
Dynamic Cone Test ——— | Undrained Triaxial at Overburden Pressure, % Strain at Failure 0 / 15 ⊕ 5 / 10
Shelby Tube ● ● ■ | Penetrometer ▲
Field Vane Test +s
Lab Vane Test t

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg. No. Page 1
Borehole No. D4
Project No. T 3780-HY
Hole location and datum see drawing No. 1

G W L	SYMBOL	Soil Description	ELEV. m	DEPTH m
		CLAYEY SILT TILL: Reddish brown, mottled and weathered, fragments of shale, moist, very hard	180.78	0
		Changes to greyish brown, green, grey and red shale fragments, very moist, mottled and weathered		3
		Changes to reddish brown, till interbedded with sand and gravel till, wet to saturated, very hard		5
		Changes to greyish brown, moist		6
		SANDY SILT TILL: Reddish brown, hard, a layer of limestone with occasional silt layers	174.7	6
		Wet		9

N Value (ASTM) D1586-CSA A119.1)
20 40 60 80
Shear Strength MPa

Natural Moisture Content and Atterberg Limits % Dry Weight
10 20 30

Natural Unit Weight kN/m³

⊕80/4"
⊕ 130/10"

TL0010

Borehole Log

Trow Ltd

Auger Sample ⊠ | Natural Moisture x
SPT (N) Value ○ ○ ▨ | Plastic and Liquid Limit ⊢○
Dynamic Cone Test ——— | Undrained Triaxial at Overburden Pressure, % Strain at Failure 0 / 15 ⊕ 5 / 10
Shelby Tube ● ● ■ | Penetrometer ▲
Field Vane Test +s
Lab Vane Test τ

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg No Page 2
Borehole No. D4
Project No T 3780-HY
Hole location and datum see drawing No. 1

G W L	SYMBOL	Soil Description	ELEV m	DEPTH m	N Value (ASTM) D1586-CSA A119.1) 20 40 60 80 / Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN/m³
			170.78	10			
				11	⊕100/3"		
		Changes to brown, very moist		12	⊕80/3"		
				13			
		Greyish green shale pieces, moist		14	⊕100/6"		
				15			
		Changes to reddish, greyish brown, very moist		16			
			165.08				
		END OF BOREHOLE		17			
				18			
				19			
				20			

TL 0140

Borehole Log

Trow Ltd

Auger Sample ⊠ | Natural Moisture ×
SPT (N) Value ○ ○ ▨ | Plastic and Liquid Limit ⊢—○
Dynamic Cone Test —— | Undrained Triaxial at Overburden Pressure 0 / 15 ⊕ 5 / % Strain at Failure 10
Shelby Tube ● ● ■ | Penetrometer ▲
Field Vane Test +s
Lab Vane Test t

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg. No. Page 1
Borehole No. D5
Project No T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m
			184.80	0
		CLAYEY SILT TILL: grey, mottled, weathered, green and grey shale fragments, very moist, hard, root fibers		1
				2
		Changes to brown, occasional pieces of limestone, moist, hard		3
				4
		Wet, compact, no mottling		5
		Very wet, compact		6
		Changes to reddish brown, fragments of red shale, a layer of green shale, wet, hard		7
				8
		Changes to brown, some limestone, moist, very hard		9
			175.20	10

N Value (ASTM) D1586-CSA A119.1) 20 40 60 80
Shear Strength MPa
Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30
Natural Unit Weight kN/m³

35/7"

TL101-0

Borehole Log

Trow Ltd

Auger Sample ⊠ | Natural Moisture ×
SPT (N) Value ○ ○ ▨ | Plastic and Liquid Limit ⊢○
Dynamic Cone Test ——— | Undrained Triaxial at Overburden Pressure 0 / 15 5 / 10
Shelby Tube ● ● ■ | % Strain at Failure
Field Vane Test +s | Penetrometer ▲
Lab Vane Test t

Project HALTON ENVIRONMENTAL ASSESSMENT | Dwg. No Page 2 | Borehole No D5 | Project No. T 3780-HY

Hole location and datum see drawing No. 1

G W L	SYMBOL	Soil Description	ELEV m	DEPTH m
			174.80	10
		SANDY SILT TILL: Greyish brown, wet, hard, silt laminations, may be reworked lacustrine material		11
				12
				13
				14
		Changes to red		15
			169.40	
		END OF BOREHOLE		16
				17
				18
				19
				20

N Value (ASTM) D1586-CSA A119.1) 20 40 60 80 — Shear Strength MPa

Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30

Natural Unit Weight kN/m³

63/6"

80/5"

80/5"

100/6"

TL10r0

Borehole Log

Trow Ltd

Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Field Vane Test
Lab Vane Test

Natural Moisture
Plastic and Liquid Limit
Undrained Triaxial at Overburden Pressure
% Strain at Failure
Penetrometer

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg. No Page 1
Borehole No. D6
Project No T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m	N Value (ASTM) D1586-CSA A119.1) 20 40 60 80 Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN/m³
		CLAYEY SILT TILL: Brownish grey, mottled, weathered, fragments of shale, moist, hard		0			
				1			
				2			
		Changes to reddish brown, hard		3			
				4			
		Moist to wet, very stiff		5			
		SILTY CLAY TILL: Grey, fragments of shale, wet, very stiff		6			
		SANDY SILT TILL: Brownish red, shale fragments, moist, hard		7			
				8			
				9			
		SILTY CLAY TILL: Grey, wet, very stiff, rudimentay		10			

TL/OIrO

Borehole Log

Trow Ltd

Auger Sample ⊠ | Natural Moisture ×
SPT (N) Value ○ ○ ▨ | Plastic and Liquid Limit ⊢—○
Dynamic Cone Test ——— | Undrained Triaxial at Overburden Pressure 0 / 15 ⊕ 5 / 10 | % Strain at Failure
Shelby Tube ● ● ■ | Penetrometer ▲
Field Vane Test +s
Lab Vane Test t

Project HALTON ENVIRONMENTAL — ASSESSMENT
Dwg. No Page 2
Borehole No. D6
Project No T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m
		bedding, may be reworked lacustrine material		10
		SANDY SILT TILL: Reddish brown, shale fragments, moist, hard		11
				12
				13
		SILT: Reddish brown, small quantities of sand and shale fragments, saturated, very stiff		14
				15
		END OF BOREHOLE		16
				17
				18
				19
				20

N Value (ASTM D1586-CSA A119.1) 20 40 60 80
Shear Strength MPa
30/5"
110/6"
Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30
Natural Unit Weight kN m⁻³

TL001rd

Borehole Log

Trow Ltd

Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Field Vane Test
Lab Vane Test

Natural Moisture
Plastic and Liquid Limit
Undrained Triaxial at Overburden Pressure
% Strain at Failure
Penetrometer

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg. No. Page 1
Borehole No. D7
Project No. T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m	N Value (ASTM) D1586-CSA A119.1) 20 40 60 80 Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN/m³
			182.22	0			
		CLAYEY SILT TILL: Brown, mottled, iron oxide staining, fragments of green, yellow and grey shale, moist, hard		1			
				2			
		Changes to grey, very stiff		3			
				4			
		Changes to greyish brown, very stiff, faint motteling		5			
				6			
		Changes to grey, very moist, very stiff					
			175.6	7			
		SANDY SILT TILL WITH SOME CLAY: Reddish brown, shale fragments, very moist to wet, very hard					
				8			
		Changes to brown, moist		9	80/6"		
				10			

TLOIrO

Borehole Log

Trow Ltd

Auger Sample ⊠
SPT (N) Value ○ ○ ⊠
Dynamic Cone Test ——
Shelby Tube ● ● ■
Field Vane Test +s
Lab Vane Test t

Natural Moisture ×
Plastic and Liquid Limit ⊢—○
Undrained Triaxial at Overburden Pressure, % Strain at Failure: 0 / 15 ⊕ 5 / 10
Penetrometer ▲

Project HALTON ENVIRONMENTAL — Dwg. No. Page 2
ASSESSMENT — Borehole No. D7
Project No T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m
			172.2	10
		Changes to reddish brown, moist		11
		May be Bedrock		12
				13
			168.3	14
		END OF BOREHOLE		15
				16
				17
				18
				19
				20

N Value (ASTM) D1586-CSA A119.1)
20 40 60 80
Shear Strength MPa

Natural Moisture Content and Atterberg Limits % Dry Weight
10 20 30

⊕ 120/6"
⊕ 100/3"
⊕ 100/4"

Natural Unit Weight kN/m³

0-0071

Borehole Log

Trow Ltd

Auger Sample ⊠ | Natural Moisture x
SPT (N) Value ○ ○ ▨ | Plastic and Liquid Limit ⊢—○
Dynamic Cone Test ⟵ | Undrained Triaxial at Overburden Pressure % Strain at Failure 0 15 5 10
Shelby Tube ● ● ■ | Penetrometer ▲
Field Vane Test +s
Lab Vane Test t

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg. No. Page 1
Borehole No. D8
Project No T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH m	N Value (ASTM) D1586-CSA A119.1) 20 40 60 80 Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN m⁻³
			183.18	0			
		CLAYEY SILT TILL: Reddish brown, mottled, weathered, shale fragments, very moist, hard		1			
				2			
		Changes to greyish brown		3			
				4			
		Changes to grey, less silt, very stiff		5			
				6			
		Changes to reddish grey, trace of sand, moist, very stiff		7			
		Changes to reddish brown, trace of sand, wet, very stiff	175.0	8			
		SILTY CLAY TILL: Grey, odd fragments of shale, wet, very stiff		9			
		CLAYEY GRAVELLY TILL: Reddish brown, saturated, hard, dense, mottled, red and green gravel size lime-	173.5	10			

TL80r0

Borehole Log

Trow Ltd

Auger Sample ⊠ | Natural Moisture %
SPT (N) Value ○ ○ ▨ | Plastic and Liquid Limit ⊢—○
Dynamic Cone Test ——— | Undrained Triaxial at Overburden Pressure ⊕ 0 5 10 15
Shelby Tube ● ● ■ | % Strain at Failure
Field Vane Test +S | Penetrometer ▲
Lab Vane Test t

Project HALTON ENVIRONMENTAL — Page 2
Dwg. No
ASSESSMENT — Borehole No. D8
Project No. T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m
		stone and shale fragments	173.1	10
			172.1	11
		SANDY SILT TILL: Greyish brown, fragments of shale, moist, hard		12
		Moist to dry		13
				14
		Changes to reddish brown, very wet, occasional silt pockets		15
		END OF BOREHOLE	167.7	
				16
				17
				18
				19
				20

N Value (ASTM D1586-CSA A119.1) 20 40 60 80
Shear Strength MPa

Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30

78/7"
100/6"
60/6"
60/6"

Natural Unit Weight kN/m³

OMOTL

SITE LF-4N

Borehole Log

Trow Ltd

Auger Sample ⊠ | Natural Moisture ×
SPT 'N' Value ○ ○ ⊠ | Plastic and Liquid Limit ⊢—○
Dynamic Cone Test ——— | Undrained Triaxial at Overburden Pressure, % Strain at Failure 0 / 15 5 / 10
Shelby Tube ● ● ■ | Penetrometer ▲
Field Vane Test +s
Lab Vane Test t

Project HALTON ENVIRONMENTAL ASSESSMENT
Hole location and datum see drawing No 1

Dwg No Page 1
Borehole No E1
Project No T 3780-HY

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m	N Value (ASTM D1586-CSA A119.1) 20 40 60 80 / Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN/m³
		Topsoil, organics	183	0			
		SILTY CLAY TILL: Reddish brown, mottled, weathered, wet below 0.3 m, prominent vertical fracture at 3.8 m hard, shale fragments		1			
				2			
				3			
		Change to greyish brown		4			
				5			
		Silty sand lense 100 mm thick		6			
				7			
		Boulders		8			
				9			
		Change to reddish brown					
		Lost core due to boulder in sampler		10			

0-40 11

Borehole Log

Trow Ltd

Auger Sample
SPT (N) Value
Dynamic Cone Test
Shelby Tube
Field Vane Test
Lab Vane Test

Natural Moisture
Plastic and Liquid Limit
Undrained Triaxial at Overburden Pressure
% Strain at Failure
Penetrometer

Project: HALTON ENVIRONMENTAL ASSESSMENT
Dwg No: Page 2
Borehole No: E1
Project No: T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m	N Value (ASTM D1586-CSA A119.1) 20 40 60 80 / Shear Strength MPa	Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30	Natural Unit Weight kN/m³
				10			
				11			
				12			
				13			
			168.9	14			
		CLAY (Till Like): Grey, hard, grades to bedded silty clay, may be partly reworked lacustrine material, saturated fine sand layer between 14.8 and 15.3 m.					
			167.7	15			
		OUTWASH/TILL COMPLEX: Interbedded, brown, saturated, loose; 76 mm gravelly till, 203 mm silty sand; 76 mm sand & gravel; 76 mm silty sand; 15 mm sand & gravel; 51 mm sandy silt, etc.		16			
			165.4	17			
		CLAYEY SILT TILL: Red-brown, mottled, hard, lost core due to stone in sampler.					
				18			
				19			
			163.7				
		SAND AND GRAVEL TILL WITH SOME BOULDERS: Brown, saturated, loose to compact, sand lense 20.3 m to 20.6 m					

0-HOLE

Borehole Log

Trow Ltd

Auger Sample ☒ | Natural Moisture x
SPT (N) Value ○ ○ ☒ | Plastic and Liquid Limit ⊢—o
Dynamic Cone Test ——— | Undrained Triaxial at Overburden Pressure / % Strain at Failure 0 / 5 / 10 / 15
Shelby Tube ● ● ■ | Penetrometer ▲
Field Vane Test +s
Lab Vane Test t

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg No. Page 3
Borehole No E1
Project No. T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV m	DEPTH m
				10
				11
				12
				13
				14
		CLAYEY SILT TILL: Reddish brown, mottled, wet, hard interbedded with distorted silt and clay lenses, low stone content, appears to be reworked lacustrine material, occasional gravelly till layer	157.8	15
				16
				17
				18
				19
				20

N Value (ASTM D1586-CSA A119.1)
20 40 60 80
Shear Strength MPa

Natural Moisture Content and Atterberg Limits % Dry Weight
10 20 30

Natural Unit Weight kN/m³

0407L

Borehole Log

Trow Ltd

Auger Sample ⊠ | Natural Moisture ×
SPT (N) Value ○ ○ ▨ | Plastic and Liquid Limit ⊢—○
Dynamic Cone Test ——— | Undrained Triaxial at Overburden Pressure, % Strain at Failure 0 / 5 / 10 / 15
Shelby Tube ● ● ■ | Penetrometer ▲
Field Vane Test +s
Lab Vane Test t

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg. No.
Borehole No. E1
Project No. T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH m
				50
			152.1	
		SILTY SAND TILL WITH SOME GRAVEL: Brown, loose to compact, saturated	151.4	51
		SAND AND GRAVEL	151.2	
		SANDY SILT TILL WITH SOME GRAVEL SIZES: Brown, dense, saturated, occassional 50 mm medium to coarse sand layers, interbedded fine to medium sand and silt below 34.1 m (appears to be reworked lacustrine material)	148.4	34
		Borehole terminated at 34.6 m		

N Value (ASTM) D1586-CSA A119.1)
20 40 60 80
Shear Strength MPa

Natural Moisture Content and Atterberg Limits % Dry Weight
10 20 30

Natural Unit Weight kN/m³

TLW0r0

Borehole Log

Auger Sample ⊠
SPT (N) Value ○ ○ ▨
Dynamic Cone Test ——
Shelby Tube ● ● ■
Field Vane Test +s
Lab Vane Test t

Natural Moisture ×
Plastic and Liquid Limit |—o
Undrained Triaxial at Overburden Pressure 0 / 5 / 10 / 15 % Strain at Failure
Penetrometer ▲

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg No Page 1
Borehole No E2
Project No T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH m
			187	0
		TOPSOIL: Brown		
		SILTY CLAY TILL: Brown, mottled, weathered to 2.59 m, hard shale fragments, moist below 0.3 m, grey brown below 1.7 m, wet below 2.6 m		1
				2
				3
				4
				5
				6
				7
				8
			178.7	9
		CLAYEY SILT TILL: Brown, hard, saturated, shale fragments		
			177.7	10
		GRAVELLY SILT TILL: Loosely consolidated, may be a water laid till - no evidence of		

N Value (ASTM) D1586-CSA A119.1)
20 40 60 80
Shear Strength MPa

Natural Moisture Content and Atterberg Limits % Dry Weight
10 20 30

Natural Unit Weight kN/m³

TL/0H-0

Borehole Log

Trow Ltd

Auger Sample ⊠
SPT (N) Value ○ ○ ▨
Dynamic Cone Test ——
Shelby Tube ● ● ■
Field Vane Test +s
Lab Vane Test ℄

Natural Moisture ×
Plastic and Liquid Limit ⊢—○
Undrained Triaxial at Overburden Pressure 0 / 15 / 5 / % Strain at Failure 10
Penetrometer ▲

Project HALTON ENVIRONMENTAL ASSESSMENT
Dwg No Page 2
Borehole No E2
Project No T 3780-HY
Hole location and datum see drawing No. 1

GWL	SYMBOL	Soil Description	ELEV. m	DEPTH m
		bedding, occasional silt parting, coarse gravel is well rounded	176.4	10
		SANDY SILT TILL: Red, brown, hard, moist, shale fragments, saturated, medium sand layer between 12.2 to 12.4 m, faint bedding, occasional small boulder sizes		11
				12
			170.8	13
		SILTY SAND AND GRAVEL TILL: Brown, saturated, poorly sorted, compact, no bedding, pebbles break clean from sandy silt matrix		14
			169.6	15
		SILT TILL WITH SOME SAND: Brown, shale fragments, dense, fissile, saturated, becomes dry to moist at 15.4 m		16
			167.0	17
		SHALE/TILL COMPLEX: Zones of red shale and brown sandy silt till, dry		18
			165.3	19
		Hole terminated in red and green shale at 18.7 m		20

N Value (ASTM) D1586-CSA A119.1) 20 40 60 80
Shear Strength MPa

Natural Moisture Content and Atterberg Limits % Dry Weight 10 20 30

Natural Unit Weight kN/m³

ILHORO

8.3.5 BOREHOLE LOGS - MINISTRY OF TRANSPORTATION AND COMMUNICATIONS

Borehole locations are shown in Figure 4 (in map pocket).

Copies of borehole records and reports were supplied by the Ministry of Transportation and Communications office at Downsview from their GEOCRESS data system and are on file.

Borehole elevations are provided to the nearest tenth of a foot in the original data. Elevations have been rounded to the nearest metre in Figure 4.

DEPARTMENT OF HIGHWAYS ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 1

FOUNDATION SECTION

JOB 69-F-51 LOCATION Sta. 306 + 03 23.5' Lt. ORIGINATED BY IV
W/P 132-65 BORING DATE July 16, 17, 18, 21, 1969 COMPLETED BY IV
DATUM Geodetic BOREHOLE TYPE Wash Boring - Diamond Drill CHECKED BY

SOIL PROFILE: ELEVATION / DESCRIPTION / STRATA PLOT	SAMPLES: NUMBER / TYPE / BLOWS/FOOT	ELEVATION SCALE	DYNAMIC PENETRATION RESISTANCE: BLOWS PER FOOT (20 40 60 80 100); SHEAR STRENGTH PSF (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE)	WATER CONTENT % (LIQUID LIMIT, PLASTIC LIMIT, WATER CONTENT; 10 20 30)	REMARKS
Ground Level					
607.0 Topsoil	1 SS 19				6 15 59 20
2.0	2 SS 8				
	3 SS 51		Col. 1		
	4 SS 100	600			
	5 SS 100/6"		198/12"		
Het. mix. of clayey silt, sand & gravel - Till Hard & Very Dense	6 SS 115				12 32 45 11
	7 SS 100	590			
	8 SS 100/6"				
	9 SS 100/3"	580			47 36 (17)
	10 SS 285				
569.2		570			
38.0 End of Borehole					

MTC-26-1

DEPARTMENT OF HIGHWAYS ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No 2

FOUNDATION SECTION

JOB C)-P-74 LOCATION Sta. 306 + 83 30.7' Lt.
W P 152-65 BORING DATE July 10, 11, 1969
DATUM Geodetic BOREHOLE TYPE Overburden - Diamond Drill

ORIGINATED BY NV
COMPILED BY NV
CHECKED BY

SOIL PROFILE ELEV. (FEET) / (METRES)	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	BLOWS/FOOT	RECOVERY	DYNAMIC PENETRATION RESISTANCE BLOWS/FOOT 20 40 60 80 100	SHEAR STRENGTH PSF ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE	WATER CONTENT % 10 20 30	REMARKS
591.6	Ground Level									
591.9 / 0.0	Topsoil		1	SS	121/5"					
			2	SS	120	590		212/12"		
			3	SS	98/8"					
	Mat. mix. of clayey silt, sand & gravel - till		4	SS	241/7"					19 36 40 5
			5	SS	92/8"	580				
	Very dense		6	SS	62/3"					
571.4 / 20.5	Bedrock		7	SS	50/3"	570				
	Calcareous Shale		8	RX						
570.9 / 21.1	End of Borehole									
						560				

MTC-26-2

OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No. 3

FOUNDATION SECTION

JOB	69-F-54	LOCATION	Sta. 306 + 73 26.6' Rt.
W/P	132-65	BORING DATE	July 8, 9, 1969
DISTRICT	Cochrane	BOREHOLE TYPE	Washboring - Diamond Drill

ORIGINATED BY IW
COMPILED BY IW
CHECKED BY

ELEV. DEPTH	SOIL PROFILE DESCRIPTION	STRAT PROF	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES BLOWS/FOOT	ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE, BLOWS/FOOT 20 40 60 80 100 / SHEAR STRENGTH PSF ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE	LIQUID LIMIT * PLASTIC LIMIT * WATER CONTENT * * * * WATER CONTENT % 10 20 30	BORE HOLE DENSITY PCF	REMARKS % GRAVEL % SAND % SILT % CLAY
597.6	Ground Level									
595.6 2.0	Topsoil		1	SS	22					
			2	SS	101	590				28 39 30 3
			3	SS	100/6"		139/12"			
	Not mix. of clayey silt, sand & gravel - Till		4	SS	50/3"					
			5	SS	100/3"					
	Very dense		6	SS	100/3"	580				30 36 27 7
572.1 25.5	Bedrock - Calc. sand		7	SS	100/3"					
			8			570				
572.1	End of Borehole									
						560				

DEPARTMENT OF HIGHWAYS, ONTARIO
MATERIALS & TESTING OFFICE

RECORD OF BOREHOLE No 4

FOUNDATION SECTION

JOB 69-F-04 LOCATION Sta. 306 + 18 27.8' Rt. ORIGINATED BY BV
SYP 132-65 BORING DATE July 14, 15, 1969 COMPILED BY BV
DATUM Geodetic BOREHOLE TYPE Washboring - Diamond Drill CHECKED BY

SOIL PROFILE ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100 / SHEAR STRENGTH PSF ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE	LIQUID LIMIT PLASTIC LIMIT WATER CONTENT % 10 20 30	REMARKS
597.5	Ground Level								
595.5 2.0	Topsoil		1	SS	17				
	Hot. mix. of clayey silt, sand & gravel - [illegible]		2	SS	142	590	136/12"		8 17 67 8
			3	SS	150				
			4	SS	141				
			5	SS	150/3"	580			
			6	SS	150/3"				13 37 41 9
[illegible]			7	SS	150/3"	570			
[illegible] 5	Bedrock		8	RX					
[illegible] 0	Calcar[illegible] Shale								
[illegible] 5	End of Borehole					560			

8.4 SUPPORTING CALCULATIONS AND METHODS

In 1856, the French hydraulics engineer Henry Darcy reported that flow through a porous medium is proportional to the head loss and inversely proportional to the distance travelled. The formulation of these relationships is called Darcy's Law and may be written as specific discharge (v) = hydraulic conductivity (K) x gradient (i). The specific discharge is the total discharge per unit area of the discharging porous medium and does not indicate the velocity of the water 'particles'. The velocity of the water (average linear velocity, $\bar{v}$) may be obtained by dividing the specific discharge (v) by the effective porosity (n) of the porous medium. Because effective porosity is always less than 1, the average linear velocity ($\bar{v}$) is always greater than the specific discharge (v).

$$\text{Average Linear Velocity } (\bar{v}) \qquad \frac{\text{hydraulic conductivity (K) x gradient (i)}}{\text{effective porosity (n)}}$$

Lateral Ground Water Flow

Once the above parameters are known for a porous medium, an average linear velocity may be calculated. The following example utilizes values typical of lateral flow in the fractured zone:

- hydraulic conductivity (K) $1\text{x}10^{-7}$
- lateral gradient (i) 0.008
- effective fracture porosity (n) 0.0001

$$\bar{v} = \frac{Ki}{n} = \frac{1\text{x}10^{-7}\text{x}0.008}{0.0001} = 8\text{x}10^{-6} \text{ m/s or } \tilde{\sim}250 \text{ m/year.}$$

Vertical Ground Water Flow

The application of Darcy's Law to ground water flow through layered porous media when the layers have differing thicknesses and hydraulic properties is discussed in Freeze and Cherry (1979) and is summarized below with regard to the area under study. The layered porous media of interest here are the confining layer subunits which include the fractured and the unfractured zones of the Halton Till and the lower till. Estimating the rates of ground water flow in each of these layers involves (1) the calculation of a single equivalent hydraulic conductivity for the three layers, (2) calculation of the specific discharge through the layers and (3) the calculation of average linear velocities in each of the layers.

The calculation of an equivalent hydraulic conductivity (Ke) for the three-layer situation is:

$$Ke = \frac{d(FCL + CL + LT)}{\frac{dFCL}{KFCL} + \frac{dCL}{KCL} + \frac{dLT}{KLT}}$$

where K and d are the hydraulic conductivity and thickness respectively and the subscripts are 'e'(equivalent), FCL (fractured confining layer),'CL'(confining layer) and'LT' (lower till).

The calculation of specific discharge (v) uses the equivalent hydraulic conductivity (Ke) and the overall vertical gradient (i) across the layers in Darcy's Law:

$$v = Ki$$

And finally, the average linear ground water velocity ($\bar{v}$) in each layer is obtained by dividing the specific discharge (v) by the effective porosity (n) for each of the layers involved.

The following example uses numbers similar to those in the report (values relate to the layers identified above; thicknesses are in m and hydraulic conductivities are in m/s).

$$Ke = \frac{14.7}{\frac{5.0}{1x10^{-7}} + \frac{6.6}{1x10^{-9}} + \frac{3.1}{1x10^{-8}}} = \frac{14.7}{7.0x10^{9}} = 2.1x10^{-9} \text{ m/s}$$

where the vertical gradient (i) is 0.2

$$v = Kei = 2.1x10^{-9} \times 0.2 = 4.2x10^{-10} \text{ m/s}$$

The average linear velocity ($\bar{v}$) = specific discharge divided by the effective porosity for each individual layer.

For the fractured confining layer, effective porosity (n) = 0.0001 and the average linear velocity ($\bar{v}$) =

$4.2x10^{-10}/0.0001 = 4.2x10^{-6}$ m/s or 1.3 m/year.

For the unfractured confining layer, no effective porosity value is available and consequently a total porosity value of 0.3 is used to calculate an average linear velocity (v):

$$4.2\text{x}10^{-10}/0.3 = 1.4\text{x}10^{-9} \text{ m/s}$$
$$\text{or } 4.4\text{x}10^{-2} \text{ m/year.}$$

For the lower till, no effective porosity value is available, and consequently a total porosity value of 0.3 is used to calculate an average linear velocity:

$$4.2\text{x}10^{-10}/0.3 = 1.4\text{x}10^{-9} \text{ m/s}$$
$$\text{or } 4.4\text{x}10^{-2} \text{ m/year.}$$

(These are approximate values and are usually rounded to one significant figure in the text).

The major assumptions for these calculations are:

(1) steady state estimated flow
(2) flow in a direction perpendicular to the layering
(3) layers are homogeneous and isotropic, and
(4) flow is governed by Darcy's Law. A more complete and theoretical discussion is given in Freeze and Cherry (1979).

For a more accurate discussion of ground water flow rates through the confining layer based on advection and diffusion calculations, the reader is referred to Appendix A of the report entitled "Site Selection Process; Phase 4A, Selection of Preferred Site(s), Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

8.5 GLOSSARY OF SELECTED TERMS

Sources are provided at the rear of this section and are referenced by the bracketed number following each definition.

Some definitions are altered slightly to reflect useage in this report and may not reflect the wide range of meanings provided in the source.

8.5 GLOSSARY OF SELECTED TERMS

Alluvium
Sediment composed of organic material, clay, silt, sand, gravel cobbles, or boulders deposited by postglacial streams. (2)

Aquifer
A body of sediment (or rock) that contains sufficient saturated permeable material to conduct ground water and yield economically significant quantities of ground water to wells and springs.(2)

Bearing Pressure (Allowable)
Means the maximum pressure that may be safely applied to a soil or rock by the foundation unit in design under expected loading and subsurface conditions. (8)

Confining Bed (Layer)
A body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers. (1)

Darcy's Law
For the velocity of percolation of water in saturated soil: Velocity = coefficient of permeability x hydraulic gradient. (4) (hydraulic conductivity is used in place of coefficient of permeability in this report).

Desiccated Crust
The exposure of fine-grained sediments to drying is accompanied by shrinkage and possibly cracking. Precompression of the upper portions of clay layers by drying is frequently observed in many of the profiles encountered in practice. The effects of desiccation are an increase in strength and a decreased water content. (6)

Drawdown
The lowering of the water level in a well as a result of withdrawal. (1)

Drift
A general term applied to all rock material (clay, silt, sand, gravel, boulders) transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier. (1)

Evaporite
A nonclastic sedimentary rock composed primarily of minerals produced from a saline solution as a result of extensive or total evaporation of the solvent. Examples include: gypsum, anhydrite, rock salt, primary dolomite, and various nitrates and borates. (3)

Geometric Mean
The nth root of the product of the values of n positive numbers; the antilogarithm of the mean of the logarithms of individual values. (1)

Geotechnical, Geotechnics
Pertaining to the broad field of geotechnics. The application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust for the solution of engineering problems. (1)

Glacial Lake
A lake fed predominantly by glacial meltwater or a lake in a depression in part closed by glacial ice. Includes lakes not directly adjacent to the glacier and lakes lying against or on a glacier, and fed mainly by waters derived from the melting of a glacier. (2)

Glaciofluvial
Pertaining to streams flowing from glaciers or to the deposits made by the streams. (2)

Glaciolacustrine
Pertaining to or characterized by glacial and lacustrine (lake) conditions. Material deposited in lakes affected by glacier ice, or deposited by meltwater flowing directly from glaciers into a lake. (2)

Ground Water
Subsurface water occurring below the water table (phreatic surface) in the saturated zone in which all pores are filled with water under hydrostatic pressure. This contrasts with subsurface water above the water table, which is referred to as soil moisture. (2)

Grout
A cement slurry of high water content, fluid enough to be poured or injected into spaces and thereby fill or seal them. (1)

Hardness (Water)
A property of water causing formation of an insoluble residue when the water is used with soap, and forming a scale in vessels in which water has been allowed to evaporate. It is primarily due to the presence of ions of calcium and magnesium, but also to ions of other alkali metals, other metals (e.g. iron), and even hydrogen. Hardness of water is generally expressed as parts per million as $CaCO_3$ (40 ppm Ca produces a hardness of 100 ppm as $CaCO_3$); also as milligrams per litre, and is the combination of carbonate hardness and noncarbonate hardness. (1)

Hazardous Waste
Waste that poses a present or potential danger to human beings or other organisms because it is toxic, flammable, radioactive, explosive, or has some other property that produces substantial risk to life. (1) (Use here excludes radioactive waste)

Heave
A predominantly upward movement of a surface, caused by expansion or displacement, as from swelling clay, removal of overburden, seepage pressure, or frost action. (1)

Hydraulic Gradient
In an aquifer, the rate of change of total head per unit of distance of flow at a given point and in a given direction. (1)

Hydraulic Head
The height of the free surface of a body of water above a given subsurface point. (1)

Hydraulic conductivity
The proportionality factor in Darcy's law as applied to the viscous flow of water in soil, that is, the flux of water per unit gradient of hydraulic potential. (3)

Hydrogeology
The science that deals with subsurface waters and with related geologic aspects of surface waters. (1)

Hydrostratigraphic Unit
A term proposed by Maxey (1964, p. 126) for a body of rock having considerable lateral extent and composing "a geologic framework for a reasonably distinct hydrologic system". (1) (used here for soil and rock).

Infiltration
The flow of a fluid into a solid substance through pores or small openings; specifically the movement of water into soil or porous rock. (1)

Lamina
The thinnest recognizable unit layer of original deposition in a sediment or sedimentary rock, differing from other layers in colour, composition, or particle size; specifically such a sedimentary layer less than 1 cm in thickness (commonly 0.05-1.00 mm thick). (1)

Log
A continuous record as a function of depth, usually graphic and plotted to scale on a narrow paper strip, of observations made on the rocks and fluids of the geologic section exposed in a well bore. (1) (used here for soil and rock).

Moraine
Accumulation of glacial material (mainly till) deposited by glaciers. (2)

Particle Size Classification System (9)

Name	Qualifying Term	Approximate Particle Size (mm)
Boulders		>200
Cobbles		60-200
Gravel	(Pebble)	2-60
Sand	Coarse	0.6-2
	Medium	0.2-0.6
	Fine	0.06-0.2
Silt		0.002-0.06
Clay		<0.002

Permeability
The capacity of a porous medium to transmit a liquid or gas subjected to an energy gradient (in the case of water, hydraulic gradient). (2)

Porosity
The ratio of the volume of voids to the total volume of a soil sample. (4). Effective porosity is the amount of interconnected space available for fluid transmission (3).

Quaternary
The youngest period of the two geologic time divisions of the Cenozoic Era. The Quaternary is subdivided into the Pleistocene and Recent (or Holocene) Epochs. It comprises all geologic time and deposits from the end of the Tertiary (approximately 2 million years ago) until and including the present. (2)

Saturated
Said of the condition in which the interstices of a material are filled with a liquid, usually water. It applies whether the liquid is under greater than or less than atmospheric pressure, so long as all connected interstices are full. (1)

Settlement
Downward movement of a structure such as a railway bridge, dam, or building, due to compression or movement of the soil below it. (4)

Shear Strength
The internal resistance offered to shear stress. It is measured by the maximum shear stress, based on original area of cross-section, that can be sustained without failure. (5)

Two extreme conditions may be recognized: drained conditions, under which the changes in stress are applied so slowly with respect to the ability of the soil to drain that no excess pore pressures develop, and undrained conditions, under which the stresses are changed so rapidly with respect to the ability of the soil to drain that no dissipation of pore pressure takes place. (7)

Slug Test
A method of determining in situ hydraulic conductivity in a single piezometer by causing an instantaneous change in the water level by adding or displacing a known volume of water. (10)

Split Spoon Sampler
Sampling spoons for exploratory borings commonly consist of a pipe with an inside diameter of about 35 mm and an outside diameter of about 51 mm. The pipe is split lengthwise. Consequently the sampler is called a split spoon. While the sample is being taken, the two halves of the spoon are held togther at the ends by short pieces of threaded pipe. One piece serves to couple the spoon to the wash pipe. The other, which has been sharpened, serves as the cutting edge while the spoon is driven into the soil. Exact dimensions are designated in ASTM DI586-67. (7)

Static (Water) Level
That water level of a well that is not being affected by withdrawal of ground water. (1)

Stratigraphic Unit
A stratum or body of adjacent strata recognized as a unit in the classification of a rock sequence with respect to any of the many characters, properties, or attributes that rocks may possess. (1)

Surcharge Load
A weight per unit of area of fill great enough to consolidate the soil sufficiently to increase its strength or reduce its compressibility to the required extent within the time available. Compressible soils such as clays, loose silts, and most organic soils may be compacted by surcharging. (7)

Till
An unsorted mixture of clay, silt, sand, pebbles, cobbles and boulders deposited directly by glacier ice. (2)

Water Table
A surface in the saturated zone below ground level along which the hydrostatic pressure is in equilibrium with the atmospheric pressure. (2)

Weathering
The destructive process or group of processes by which earthy and rocky materials on exposure to atmospheric agents at or near the earth's surface are changed in colour, texture, composition, firmness, or form with little or no transport of the loosened or altered material; specifically, the physical desintegration and chemical decomposition of rock that produce an in situ mantle of waste and prepare sediments for transportion. (1)

SOURCES

(1) Glossary of Geology (Second Edition); R.L. Bates and J.A. Jackson; American Geological Institute, Falls Church, Virginia, 1980.

(2) Ontario Engineering Geology Terrain Study Users' Manual; J.F. Gartner, J.D. Mollard, and M.A. Roed; Ministry of Natural Resources, 1981.

(3) Permeability and Ground Water Contaminant Transport (A Symposium sponsored by ASTM, Philadelphia, 17-23 June, 1979); ASTM Special Technical Publication 746.

(4) A Dictionary of Civil Engineering, J.S. Scott; Penguin Books, 1985.

(5) Pit Slope Manual, Chapter 5, Design; Minerals Research Program, Mining Research Laboratories, Canmet Report 77-5.

(6) Fundamentals of Soil Behaviour; J.K. Mitchell; John Wiley and Sons Inc., 1976.

(7) Soil Mechanics in Engineering Practice; K. Terzaghi and R.P. Peck; John Wiley and Sons, 1967.

(8) Canadian Manual of Foundation Engineering; Issued by The Associate Committee on the National Building Code, National Research Council of Canada; 1978.

(9) Bulletin of the International Association of Engineering Geology; (Symposium on Engineering Geological Problems of Construction on Soluble Rocks; Istanbul, Turkey, Sept. 14-18, 1981); Published by the International Association of Engineering Geology.

(10) Groundwater; J.A. Cherry and R.A. Freeze; Prentice Hall Inc., New Jersey, 604 p.

8.6 DETAILED FIELD METHODS

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8.6.1 INTRODUCTION

Field data for of the Phase 4A hydrogeologic onsite investigations were collected in a standardized fashion and formed part of the basis for geologic, hydrogeologic, and geotechnical comparisons of the eight candidate sites. An outline of the major field activities is shown in Figure 9. The study approach was modified only slightly on a site-by-site basis to accommodate differing circumstances and site conditions. Standard procedures for the drilling and sampling operations, as outlined in the Gartner Lee Associates Ltd. "Drilling and Sampling Protocol" document (GLAL 1984a), were adhered to throughout the drilling program. This protocol document provides examples of field forms used to document field activities and should be referred to for more detailed drilling and sampling procedural descriptions.

8.6.2 DRILL SITE IDENTIFICATION

8.6.2.1 Preliminary data analysis

A preliminary review of existing water well and test hole data was completed to establish a basis for the selection of tentative drill locations. Criteria used included the following:

- the distribution of existing test holes and water wells;
- the continuity of existing data; and
- anomalous or unusual site conditions.

While locations were selected primarily on technical grounds, practical considerations such as site access, potential crop damage, and landownership were also taken into account.

DETAILED FIELD METHODS

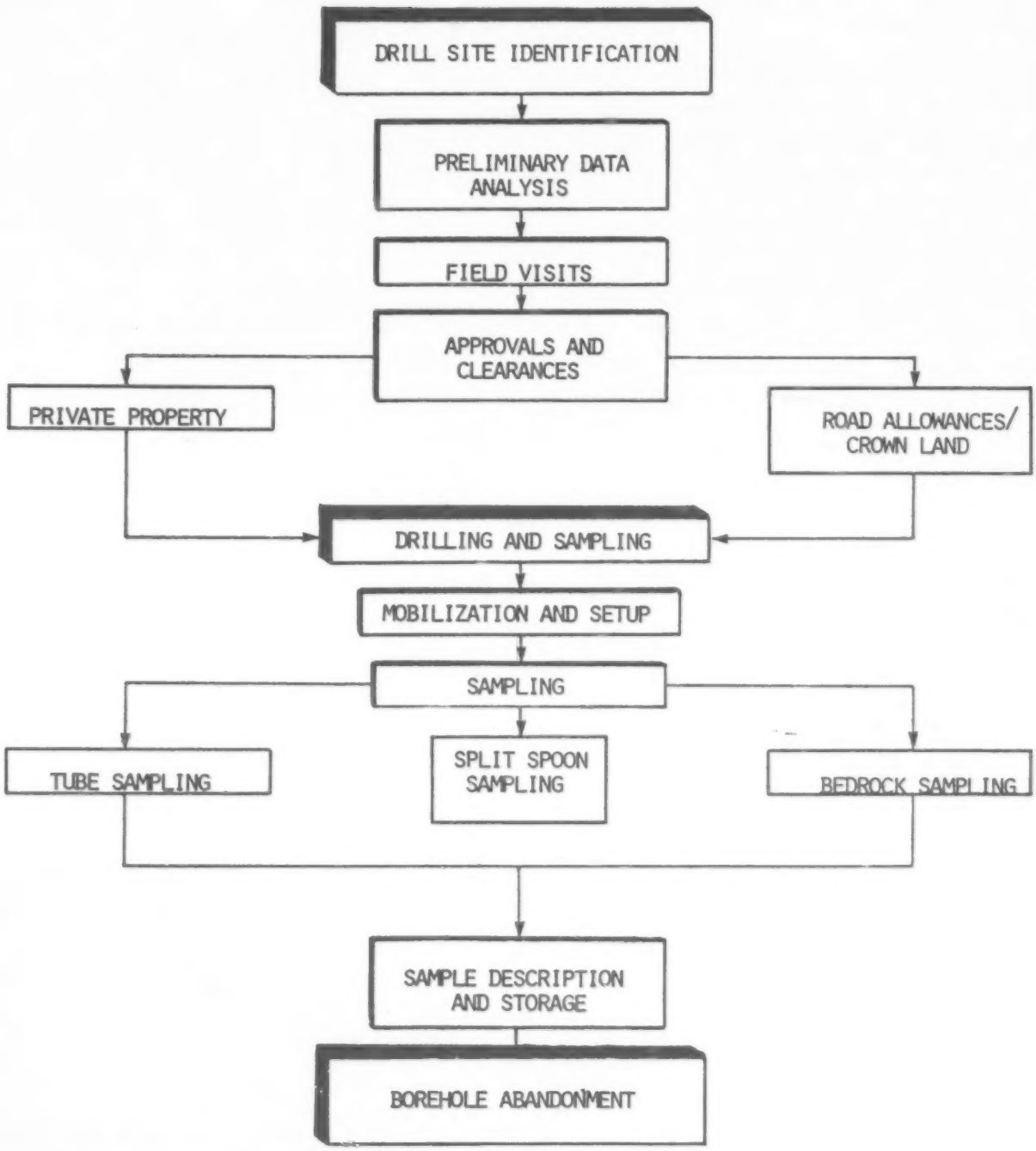


Figure 9

8.6.2.2 Field visits

The concerns of local public interest groups and individuals were also considered in selecting drill locations. Local interest groups were invited to participate during field checking of the drill locations. During these field visits, additional data on water use, local soil conditions, and wells were obtained from local residents. This information was used as a check on some of the field data obtained previously by Ecolgistics Limited during the 1984 "Walk and Talk" survey. The amount of information thus obtained varied from site-to-site and depended largely upon the degree of co-operation given by residents and landowners.

A limited amount of soil probing was completed at Candidate Sites LF-3C, LF-9C, and PI-13N using a 25 mm (1 inch) magnesium hand auger. These investigations were generally limited to a depth of 1 to 2 m. Hand augering was directed toward areas of suspected granular soils or anomalous soil conditions identified by local residents. Soil probing was confined to areas where property access was permitted. Soil descriptions are included under "Field Station Descriptions" in the individual technical site reports.

The tentative drill locations were adjusted during the field visits to avoid difficult or unsafe drilling locations. Each location was marked with a temporary wooden stake. Final adjustments were subsequently made, where necessary, to provide the required safe setbacks from buried and overhead services.

8.6.2.3 Approvals and Clearances

Clearances for both road allowances and adjacent private

or public property were pursued where identified drilling locations were located in the vicinity of local roads. Road allowances were drilled where access to private property was denied.

Landowners and tenants of affected properties were initially contacted by GLAL and verbal approval for test drilling was obtained. Approval was confirmed with a follow up letter from OWMC. For road allowance clearances, the appropriate agencies were contacted and the necessary permit approvals were obtained.

Utilities were contacted and buried service cables and/or pipes were field located by utility personnel and final adjustments of drill locations were completed. Drilling approvals and clearances were completed on a site-by-site basis.

8.6.3 DRILLING AND SAMPLING

8.6.3.1 Drilling equipment and setup

All Terrain Drilling Limited was retained to provide drilling services. The drilling equipment included truck and track mounted CME 75 auger drilling rigs. Two rigs were used simultaneously for most of the drilling program. Each rig was equipped to drill and sample both soils and bedrock. Each rig was staffed with a three man drilling crew and supervised by a GLAL geologist. The drilling program was initiated on August 13, 1984 at Site LF-3C and was completed on November 22, 1984 at Site LF-4N.

The drill rigs were set up in accordance with standard drilling practices and in a manner that allowed the safe

and efficient operation of the equipment. A safety corridor was roped-off around the drill rig to limit access to the rigs. Access to the roped-off area was restricted to individuals with proper safety equipment which included steel-toed boots and a hard hat. A record was kept of all visitors to the drill site as well as persons entering the roped-off area.

Sample documentation and storage facilities were set up at the edge of the roped-off area by GLAL. Soil and rock samples were accessible to the general public for viewing and/or photographing as the samples were being logged by the onsite geologists. Samples were subsequently sealed in tubes or core boxes, labelled, and placed in storage. On several occasions, soil sample tubes were re-opened for examination at the request of local residents.

8.6.3.2 Soil sampling

The drilling program was designed to obtain a continuous column of soil from the ground surface to and including the upper few metres of the underlying bedrock. Soil samples were obtained using hollow stem auger drilling techniques. Hollow stem augers (108 mm (4.25 inch) inside diameter) were used throughout the drilling program.

Split tube sampling. Tube samples measuring approximately 89 mm (3.5 inches) in diameter by 1.52 m (5 ft.) in length were taken continuously from ground level to the bedrock surface. The tube sampler consisted of a split tube with a bevelled sampler tip. The split tube was threaded at both ends and fastened to the drill rods as shown in Figure 10. The sampler as advanced inside the hollow stem augers with

Continuous Soil Sampling With Split Tube Sampler

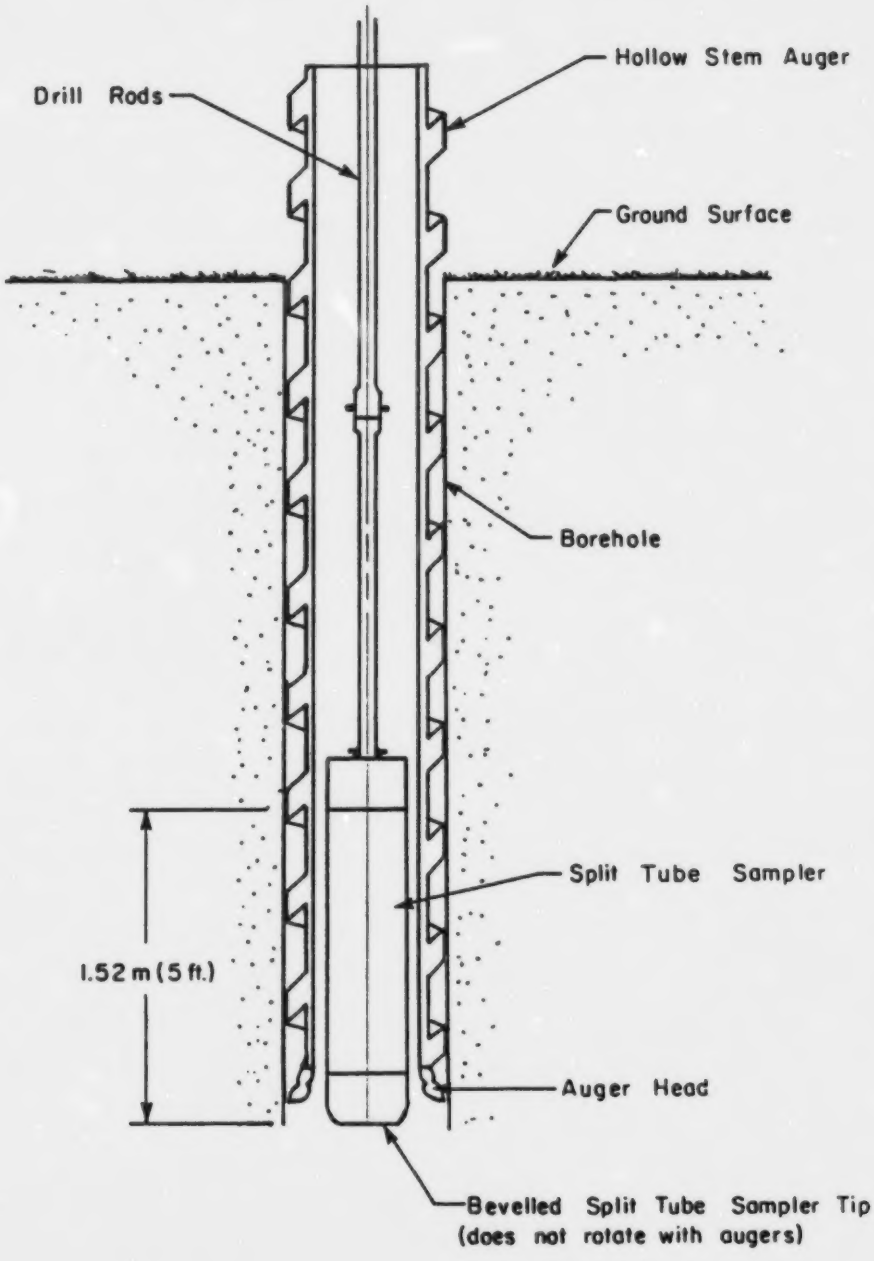


Figure 10

the bevelled tip slightly ahead of the cutting edge of the augers. A split tube sample was obtained by advancing the sampler with the rotating augers. The augers and sampler were advanced at about 1.52 m (5 ft.) intervals or until refusal, and the sampler was then withdrawn from the borehole. The soil sample was removed from the tube and the sampler washed with clean water. Sample recovery for the tube samples was generally between 90 to 100% and was recorded in the field log. Difficult drilling conditions or large cobbles occasionally resulted in lower sample recovery.

Split spoon sampling. Standard split spoon samples were taken at about 1.52 m (5 ft.) intervals throughout the soil sequence overlying bedrock and beginning at about 1.52 m 5 ft.) from the ground surface. Sample intervals are shown schematically in Figure 11.

The split spoon sampler was driven by dropping a 63.5 kg (140 lb.) weight a distance of about 750 mm (30 inches). The sampler was inserted inside the hollow stem augers in a similar fashion to the tube sampler. It was then driven into the soil below the bottom of the augers a distance of about 460 mm (18 inches) or until refusal. The number of blows required to advance the sample for each interval of about 150 mm (6 inches) was recorded in the field log. The split spoon was usually withdrawn when 50 or more blows were required to advance the sampler approximately 150 mm (6 inches) into the subsoil.

Standard split spoon samples were obtained in place of tube samples where difficult drilling conditions were

Soil & Rock Sample Intervals, Phase 4A Drilling Program

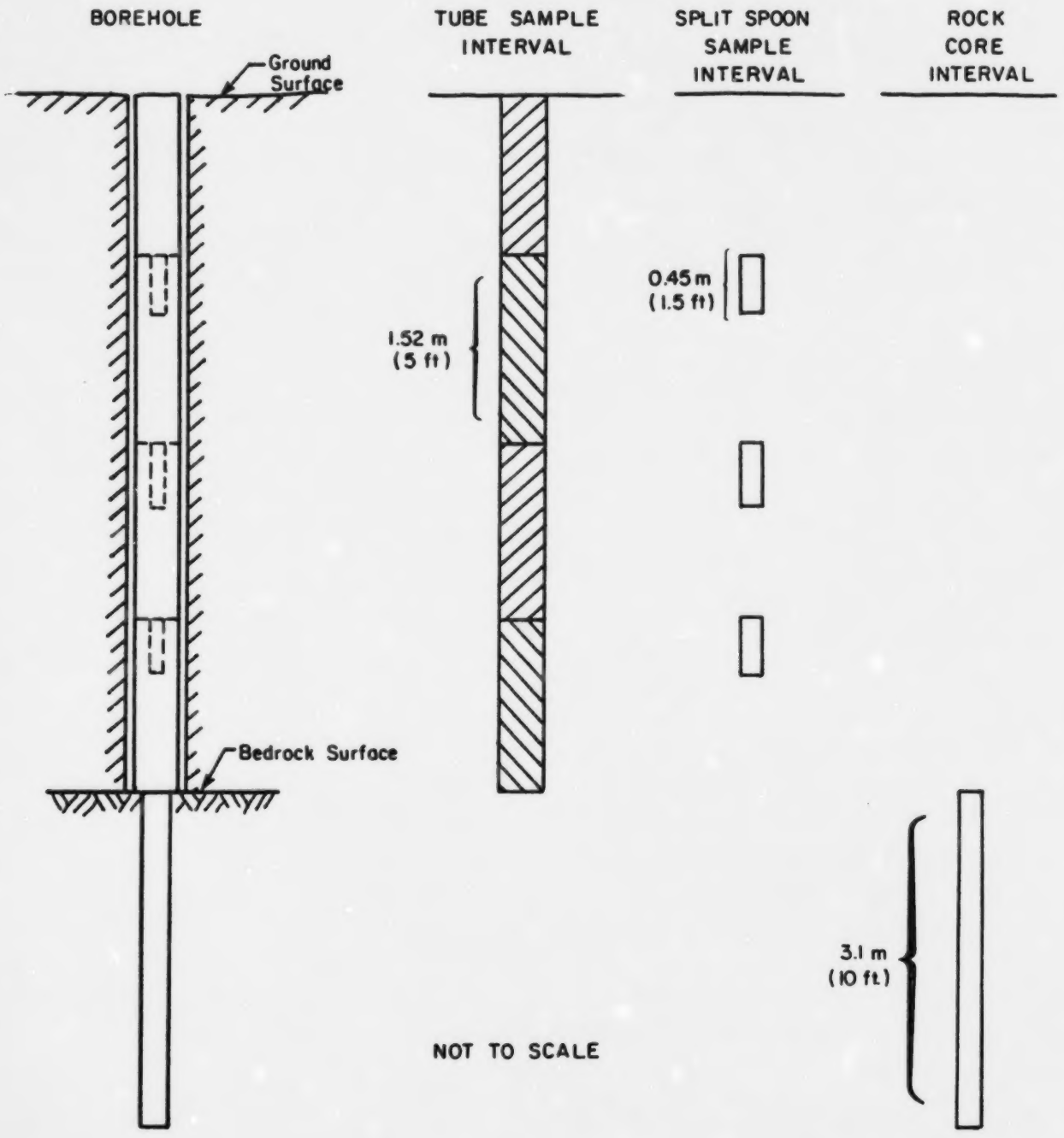


Figure 11

encountered. At Site LF-4N, Borehole 4, granular soils were encountered at a depth of about 30 m (100 ft.) causing refusal of the tube sampler. Standard split spoon samples were taken from a depth of 30 m (100 ft.) at intervals of 0.5 to 3 m (1.6 to 9.8 ft.) to a depth of about 40 m (130 ft.). Difficult soil conditions were also encountered at Site LF-2N, Borehole 1. Numerous rock fragments were encountered below a depth of about 12 m (40 ft.) at this location. Split spoon samples at 0.76 m (2.5 ft.) intervals were taken between depths of about 12 m (40 ft.) to 34 m (110 ft.).

Difficult (sandy and gravelly) soil conditions at Site PI-27E, Borehole 3 prevented tube sampling between depths of about 16 to 30 m (50 to 100 ft.). Similar fine, sandy soils were also encountered in Borehole 4 at this site at depths between approximately 24 to 30 m (80 to 100 ft.). Standard split spoon samples at 1.5 m (5 ft.) intervals were collected over these intervals at these two borehole locations.

Moisture tin samples. A small soil sample of approximately 100 grams was taken from the tip of each split spoon sample for laboratory determination of the soil moisture content. Soil moisture samples were placed in air tight tins immediately after they were taken from the split spoon samples. The moisture tin (sample) numbers were recorded on the field borehole logs. The samples were temporarily stored in the field and shipped in batches to the GLAL office for transfer to a commercial laboratory.

Rotary drilling. Rotary drilling techniques were occas-

ionally used to penetrate difficult soils that could not readily be drilled with conventional hollow stem auger drilling methods. These techniques were also used where granular soils, acting under hydraulic pressures, were forced up inside the hollow stem augers. This condition prevented the split tube and split spoon samplers from passing through the plugged portions of the hollow stem augers. Clean water or a water/bentonite mixture was circulated through a rotating tricone drill bit to clean out the material in the hollow stem augers. Rotary drilling was also used to drill through gravelly or bouldery soils such as those encountered at depth at Site LF-4N, Borehole 4, and at Site LF-2N, Borehole 1.

8.6.3.3 Bedrock sampling

Boreholes were generally completed into bedrock except in a few cases where difficult drilling conditions were encountered and the borehole was terminated before reaching bedrock.

The bedrock contact was often obscured as a result of weathering, particularly in shale. Under conditions of extreme weathering, shale was occasionally retrieved within the split tube and split spoon samplers. For example, a nearly complete 1.5 m core of weathered bedrock was obtained in the split tube sampler in Borehole 5 at Site PI-13N.

Diamond drill coring. Most bedrock samples were obtained using a diamond drill bit and NX size core barrel. Rock core samples generally measured about 53 mm (2.1 inches) in diameter and up to 3 m (10 ft.) in length. The diamond drill bit and core barrel were positioned on the bedrock

surface from inside the hollow stem augers. A rock core was obtained by the cutting action of the rotating drill bit. Clean water was circulated in the borehole to remove cuttings from around the drill bit. The water used in this operation was field checked with a Hach Kit for chlorides and sulphates to ensure compatibility with grouting materials used for borehole abandonment. The amount of water used was recorded on the field logs.

Bedrock coring was terminated when a sufficient length of sample was retrieved to prove-out the bedrock contact. The bedrock core recovered varied in length from about 1.5 m to 3 m (5-10 ft.) between borehole locations.

8.6.3.4 Sample description and storage

Soil and rock samples, taken from the boreholes, were described in detail in the field and photographed. Sample descriptions were recorded on the Field Borehole Log forms. These logs, together with the sample photos, form a permanent record of the sampling procedures.

The tube samples were transferred directly from the sampler into PVC tubular piping which was cut in half. The PVC pipe measures 89 mm (3.5 in.) inside diameter by 1.5 m (5 ft.) long. One 'side' of the sample was scraped clean along its length with a knife or spatula to facilitate sample description. Individuals and local interest groups were allowed to view the samples and make their own field notes of the samples. Soil scrapings were given to those interest groups that requested them or else were discarded. Soil samples were sealed in the PVC tubes by covering the

ends with plastic caps and taping the entire tube along the seams. Sample labels were affixed to each PVC tube.

The samples were stored temporarily in a field van until a sufficient number of samples were obtained for transport to permanent storage facilities in Toronto at the Ontario Geological Survey. Each shipment of samples were itemized on a Sample Packing list. The contents of each shipment were also recorded on a Chain of Custody Record which showed the times and dates of sample transfer as well as the individuals involved in handling the samples.

Split spoon soil samples taken during the project were described in the field and soil moisture (moisture tin) samples taken from the base of the split spoon sampler were submitted to a laboratory for analysis. The moisture tin number was recorded on the Field Borehole Log and on the Sample Packing List. In cases where a split spoon sample was taken in place of the larger split tube samples, they were stored in labelled plastic bags and retained with the other samples. The top of each bedrock core segment was marked on both the core boxes and on the rock core itself with a felt marker.

The soil and rock samples were re-examined by a senior GLAL geologist at the permanent storage area at the Ontario Geological Survey. The field descriptions were combined with the more detailed geologic log prepared by the senior geologist to compile a final borehole log. All soil samples were resealed after examination.

8.6.4 BOREHOLE ABANDONMENT

Boreholes were generally terminated after pentrating the bedrock or when difficult conditions prevented further drilling. An exception to this occurred at Site LF-1E, Borehole 3, where a gas pocket was encountered at a depth of about 17.8 m (58 ft.) in the drift. The borehole was terminated at this depth and sealed as soon as the gas pressure subsided sufficiently to allow grouting.

8.6.4.1 Grouting

On completion of each borehole all sampling equipment and temporary casing were removed from the borehole. Each borehole was then filled to the surface with a cement/bentonite slurry. This was accomplished by injecting grout through the hollow stem augers as they were slowly withdrawn from the hole as shown in Figure 12. Specifications of the slurry mix, as set out in the Drilling and Sampling Protocol Document (GLAL 1984a) were altered slightly to accommodate site conditions. The actual grout slurry mix is compared on a percent weight basis to the specified grout slurry mix below:

Specified Grout Slurry	Actual Grout Slurry
1.2% Bentonite	2-3% Bentonite
6.0% Hydrated Lime (optional)	
59.6% Cement (Portland Type 10)	40-60% Cement (Portland Type 10)
33.2% Water	37-58% Water

The increased amount of bentonite provides a more effective seal in water bearing formations. The bentonite also acts as a 'plasticizing' agent and eliminated the need

Grouting Of Borehole

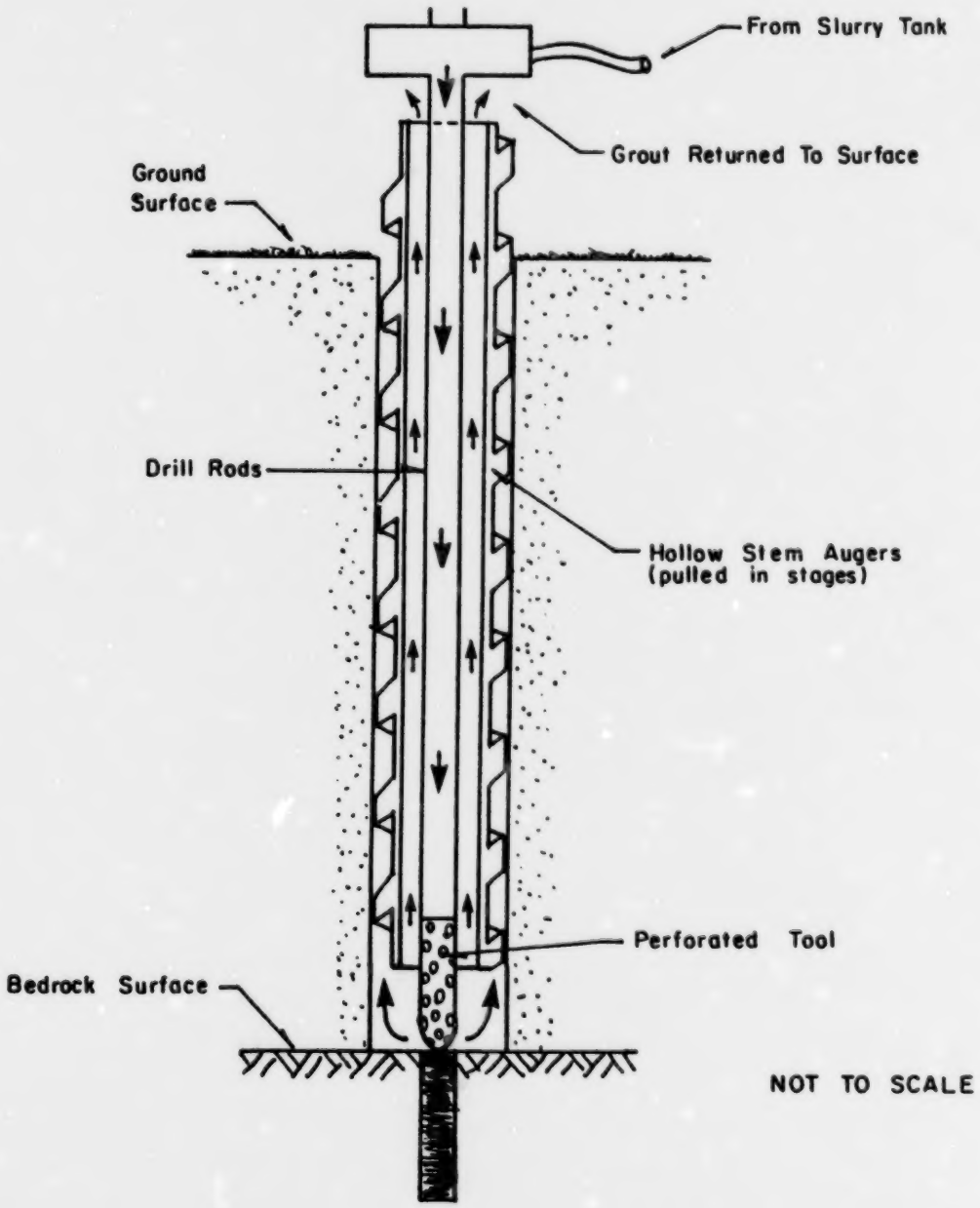


Figure 12

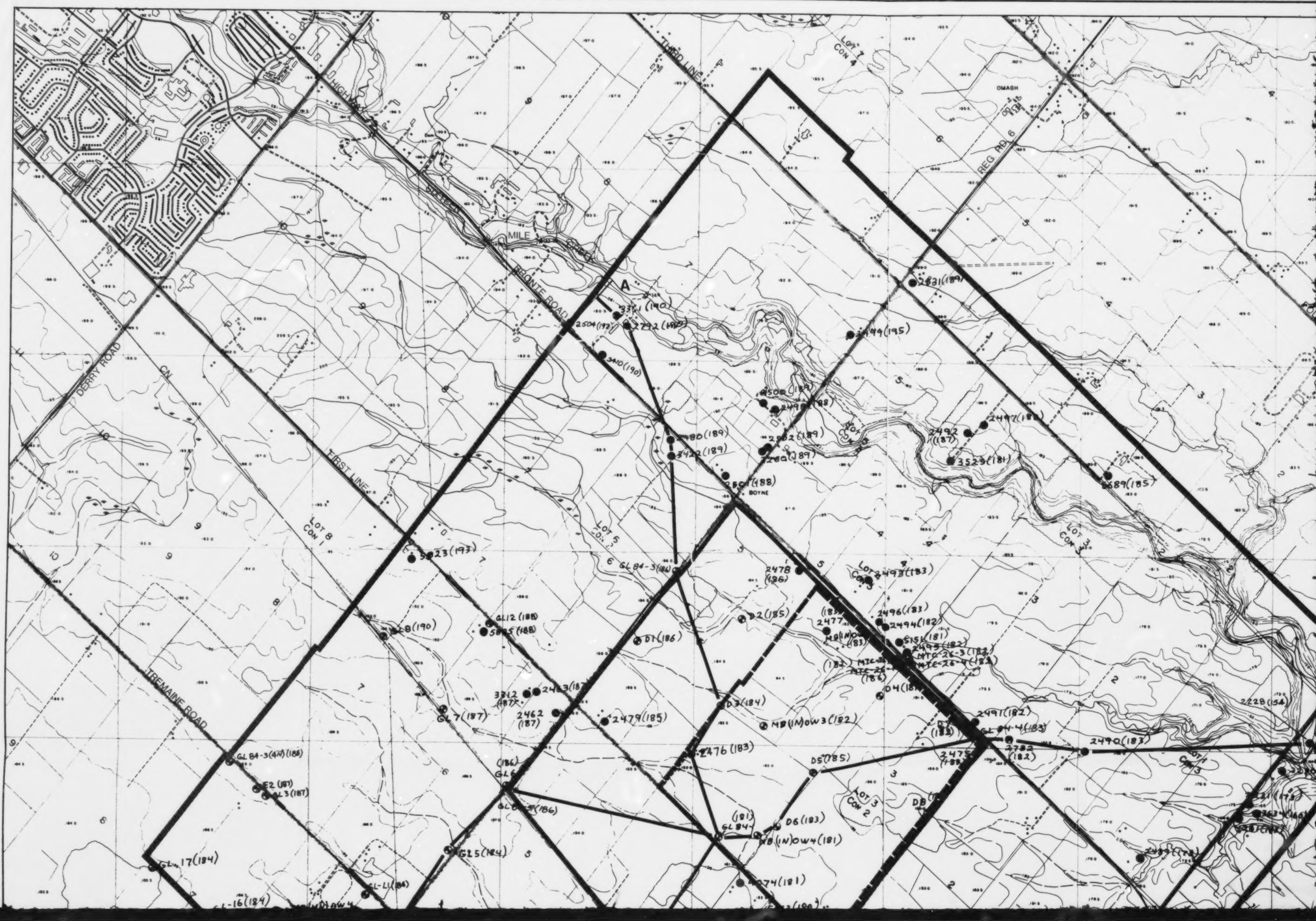
to add hydrated lime to the grout slurry mix. A cement mix containing slightly less than the amount of cement specified in the protocol was found to be adequate. A small sample of grout slurry was taken from each hole to confirm the setting characteristics of the mix.

The water used in the grout slurry was obtained locally and was tested wth a Hach Kit for sulphate and chloride content. Details of each grout mix were recorded on the Borehole Plugging Plan/Record for each borehole.

The grout was allowed to set overnight and generally settled to within 1 to 3 m (3-10 ft.) of ground surface. The hole was subsequently backfilled to grade with soil to avoid interference with surface activities such as ploughing or maintenance along road allowances. All boreholes from this drilling program were successfully grouted.

8.6.4.2 Site cleanup

Efforts were made to restore each drill location to predrilling conditions. The ground was levelled to grade and holes or ruts made by drilling equipment were filled with soil and in some cases resodded. While attempts were made to minimize damage, this was not always possible and compensation was provided in some cases. Photographs were taken of each drill location both before and after the drilling operations and after site cleanup.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BEAVER CREEK
DERRY ROAD
CN
TREMAINE ROAD
FIRST LINE
THIRD LINE
LOT 8 CON 1
LOT 5
LOT 4 CON 4
LOT 3 CON 3
LOT 3 CON 2
REG. RD. 6
OMAGH
BOYNE
A
B
C
D
GL12 (188)
GL7 (187)
GL 84-3(4M) (186)
GL 84-3(4M)
GL 84-4
GL15(184)
GL-16(184)
GL-17(184)
GL-LL(184)
E2 (187)
GL3 (187)
DT(186)
D2(185)
D3(184)
D4(184)
DS(185)
D6(183)
MB(IN)OW3(182)
MB(IN)OW4(181)
MTC-2C-3(182)
MTC-2S-4(182)
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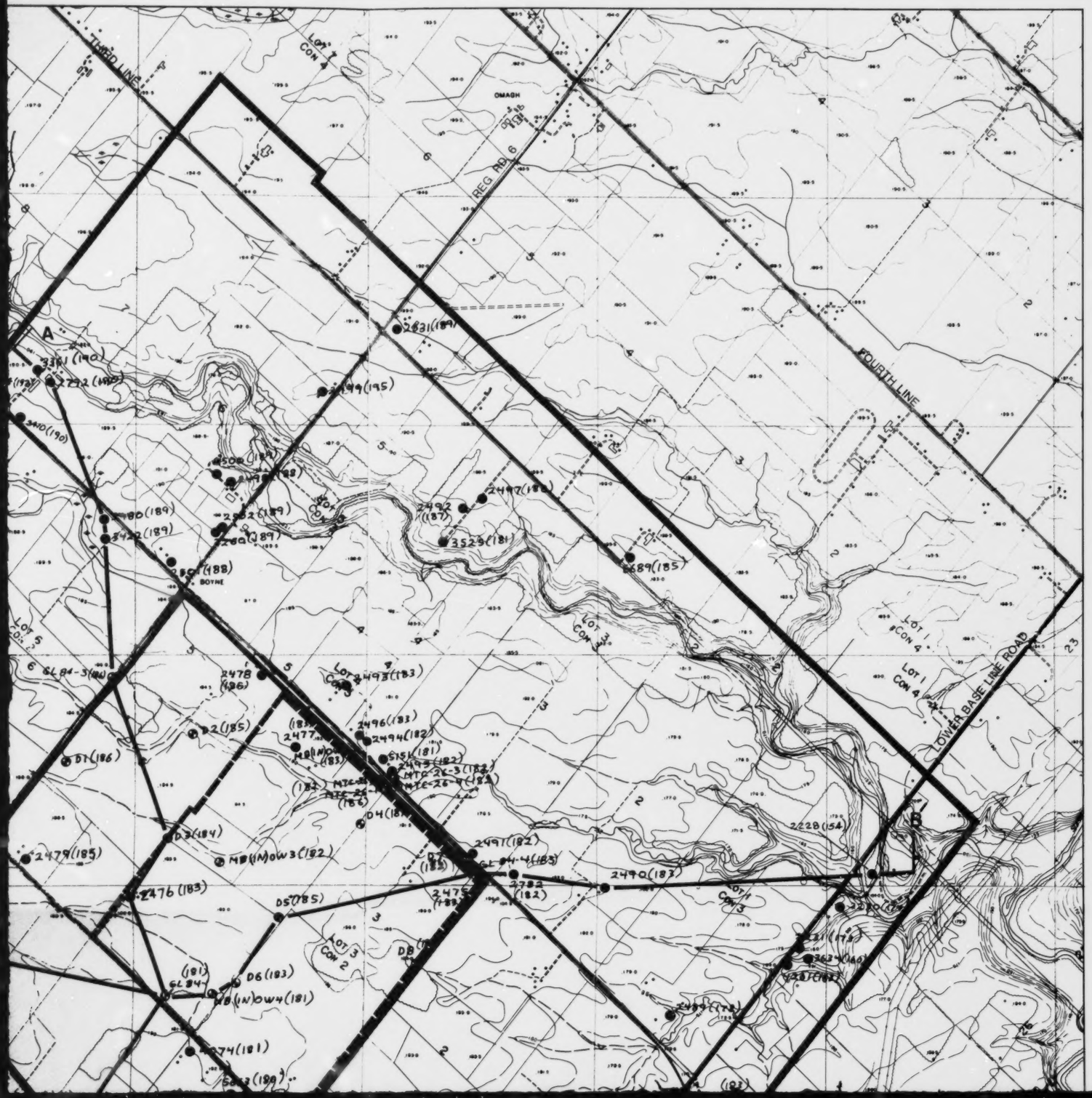


OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

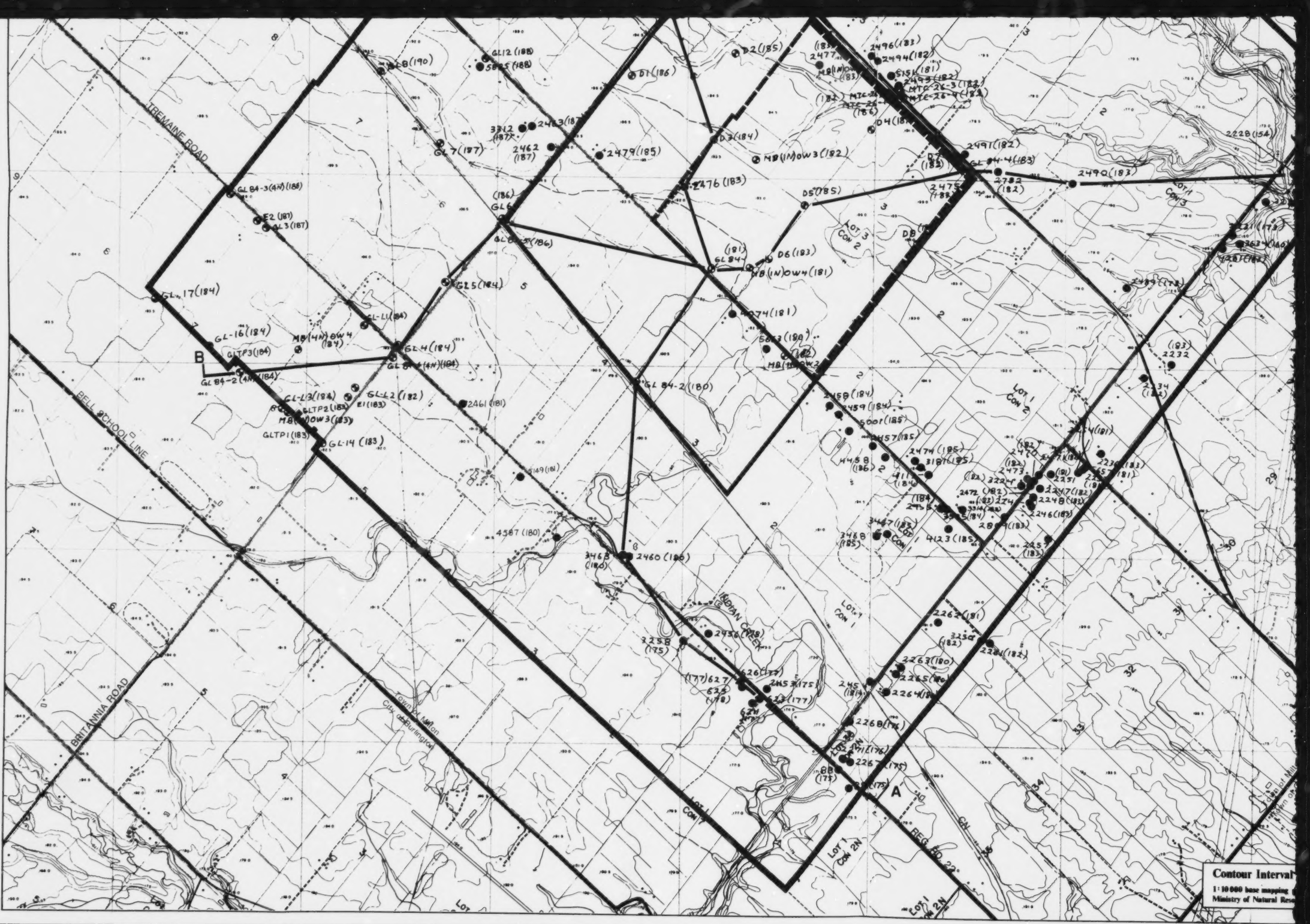
- GL 84-3 (IN) or (4N) - Gartner Lee Associates Limited borehole - 1984 - Site PI-1N or LF-4N
- GL 4 or GL-L1 - Gartner Lee Associates Limited borehole 1976 - 1979
- GLTP 1 - Gartner Lee Associates Limited Test Pit-1979
- D1 or E1 - Hydrology Consultants Limited borehole - Site PI-1N (D) or LF-4N (E)
- MB(IN)OW3 or MB(4N)OW3 - Morrison Beatty Limited borehole - Site PI-1N or LF-4N
- MTC 26-3 - Ministry of Transportation and Communications borehole
- 2437 - Water Well with Ministry of the Environment Number
- (183) - Estimated surface elevation in metres above sealevel
- A — A' Cross-Section

Proposed Acquisition Boundary
Phase 3B Acquisition Boundary
Site Vicinity Study Area Boundary

Key Map:

PI-1 North

Lots 3, 4 and 5; Concession II; Town of Milton; Parts of Lots 3, 4 and 5; Concession I; Town of Milton, formerly in the Township of Trafalgar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PELL SCHOOL LINE
BRITANNIA ROAD
Town of Milton
City of Burlington
INDIAN CREEK
REG. HD. 22°
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LOT 3 CON 2
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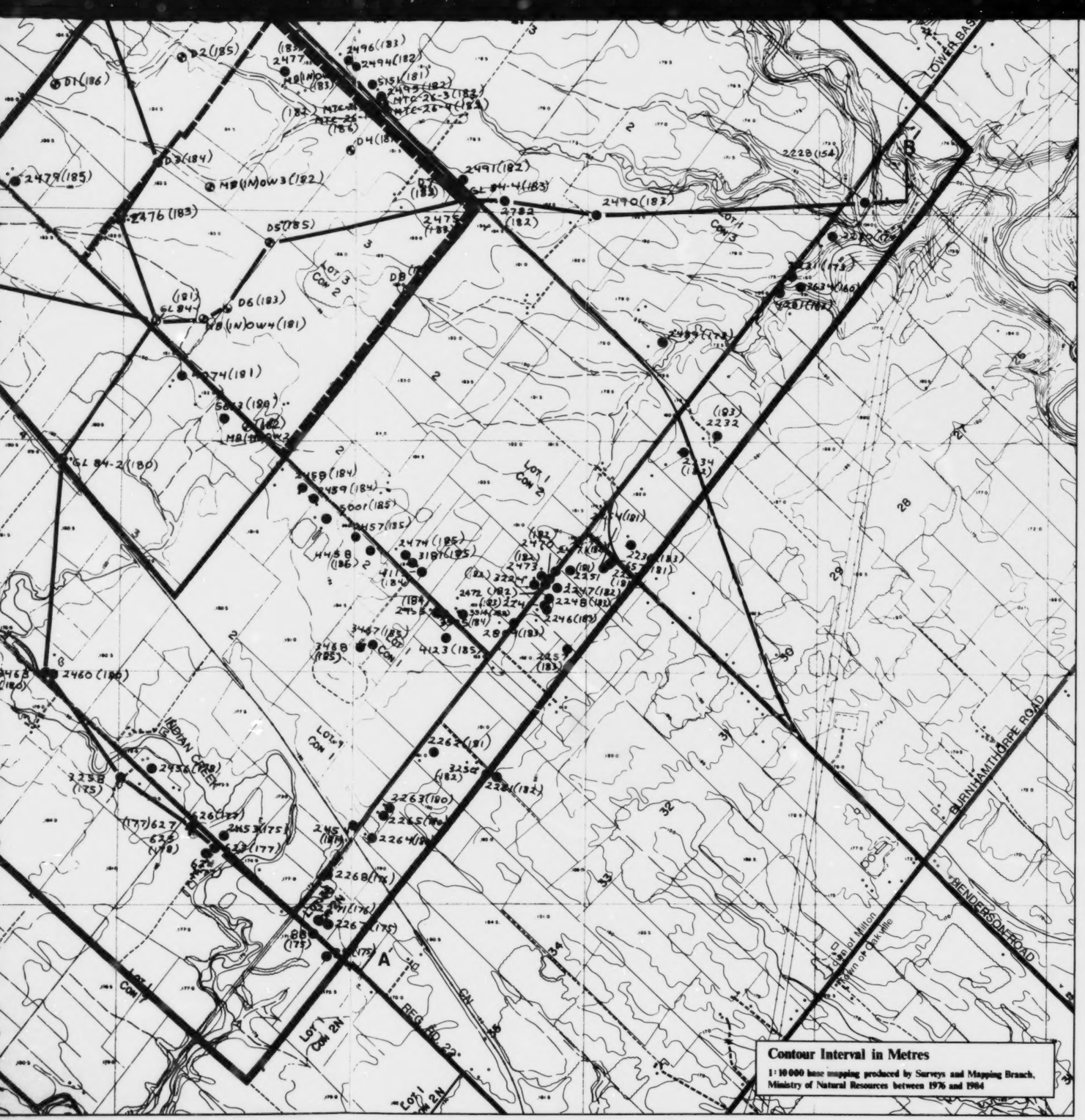
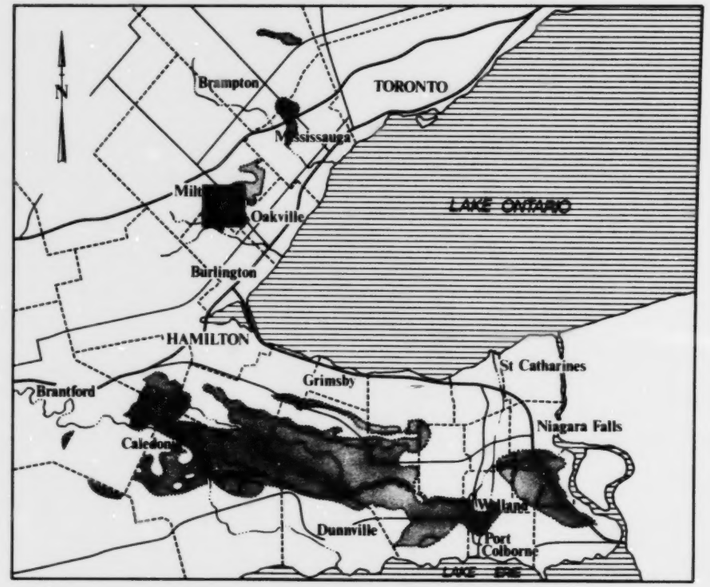


Proposed Acquisition Boundary
Phase 3B Acquisition Boundary
Site Vicinity Study Area Boundary

Key Map:



PI-1 North

Lots 3, 4 and 5; Concession II; Town of Milton; Parts of Lots 3, 4 and 5; Concession I; Town of Milton, formerly in the Township of Trafalgar

1000 feet 0 1000
500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Well and Borehole Locations

September 1985 **FIGURE 4**

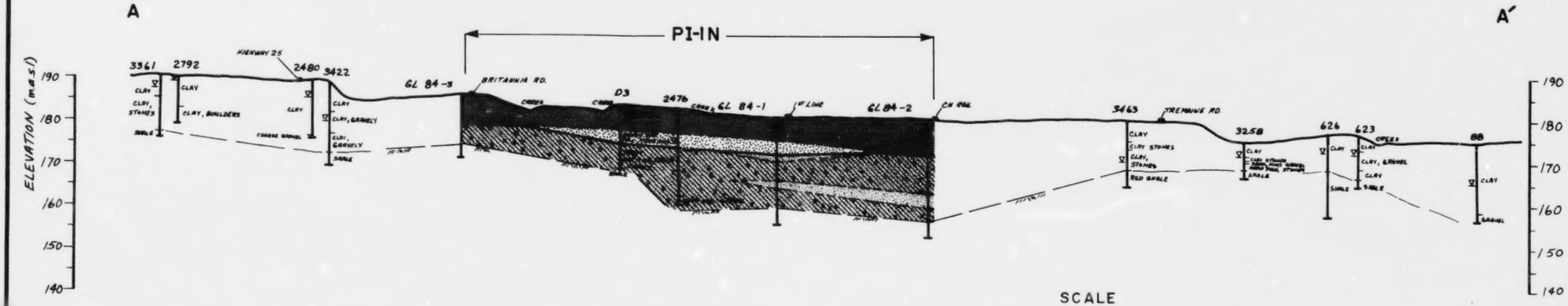
North

Looking East

South

A

A'



(Geologic conditions between boreholes may vary from interpretations shown)

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

Site PI-IN
CROSS-SECTION A-A'
Figure 5

LEGEND

GL-84	Gartner Lee Associates Limited Borehole 1984
GL	Gartner Lee Associates Limited Borehole 1978-1979
D	Hydrology Consultants Limited Borehole
MB (IN)OW3	Morrison Beatty Limited Borehole
2437	Water Well with Ministry of the Environment Number
▽	Static Water Level in Well at Time of Construction
masl	Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- SILT TO CLAYEY SILT TILL (Halton Till)
- SANDY SILT TILL (Lower Till)
- SAND + SILT
- SILTY SAND TILL (Lower Till + Sand)
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

NOTES:
- Consult Water Well Record Summary and Borehole Logs in Section B for detailed descriptions.
- Elevations are approximate
- Cross-Section Located in Figure 4
- To accompany Phase 4A Technical Appendix (Geologic Hydrogeologic and Geotechnical Considerations)

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

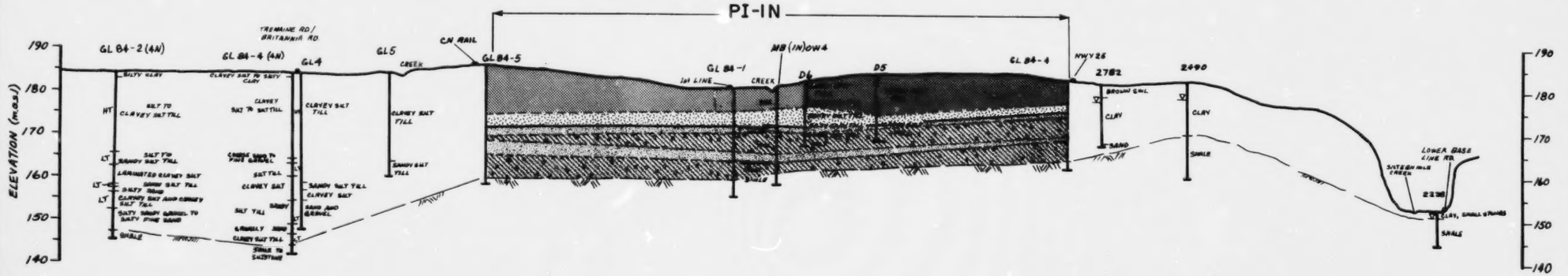
West

Looking North

East

B

B'



(Geologic conditions between boreholes may vary from interpretations shown)

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

Site PI-IN
CROSS-SECTION B-B'
Figure 6

LEGEND

GL-84	Gartner Lee Associates Limited Borehole 1984
GL	Gartner Lee Associates Limited Borehole 1978-1979
D	Hydrology Consultants Limited Borehole
MB (IN)OW3	Morrison Beatty Limited Borehole
2437	Water Well with Ministry of the Environment Number
▽	Static Water Level in Well at Time of Construction
masl	Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- SILT TO CLAYEY SILT TILL (Halton Till)
- SANDY SILT TILL (Lower Till)
- SAND + SILT
- SILTY SAND TILL (Lower Till + Sand)
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

NOTES:
- Consult Water Well Record Summary and Borehole Logs in Section B for detailed descriptions.
- Elevations are approximate
- Cross-Section Located in Figure 4
- To accompany Phase 4A Technical Appendix (Geologic Hydrogeologic and Geotechnical Considerations)

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

DERRY ROAD
CN
TREMAINE ROAD
HIGHWAY 25
MILE CREEK
BRONTE ROAD
THIRD LINE
FIRST LINE
REG. RD. 6
OMAGH
BOYNE
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LOT 5 CON 2
LOT 7 CON 4
LOT 4 CON 3
LOT 3 CON 2
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GL 84-5 14.7
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GL 84-3 6.9
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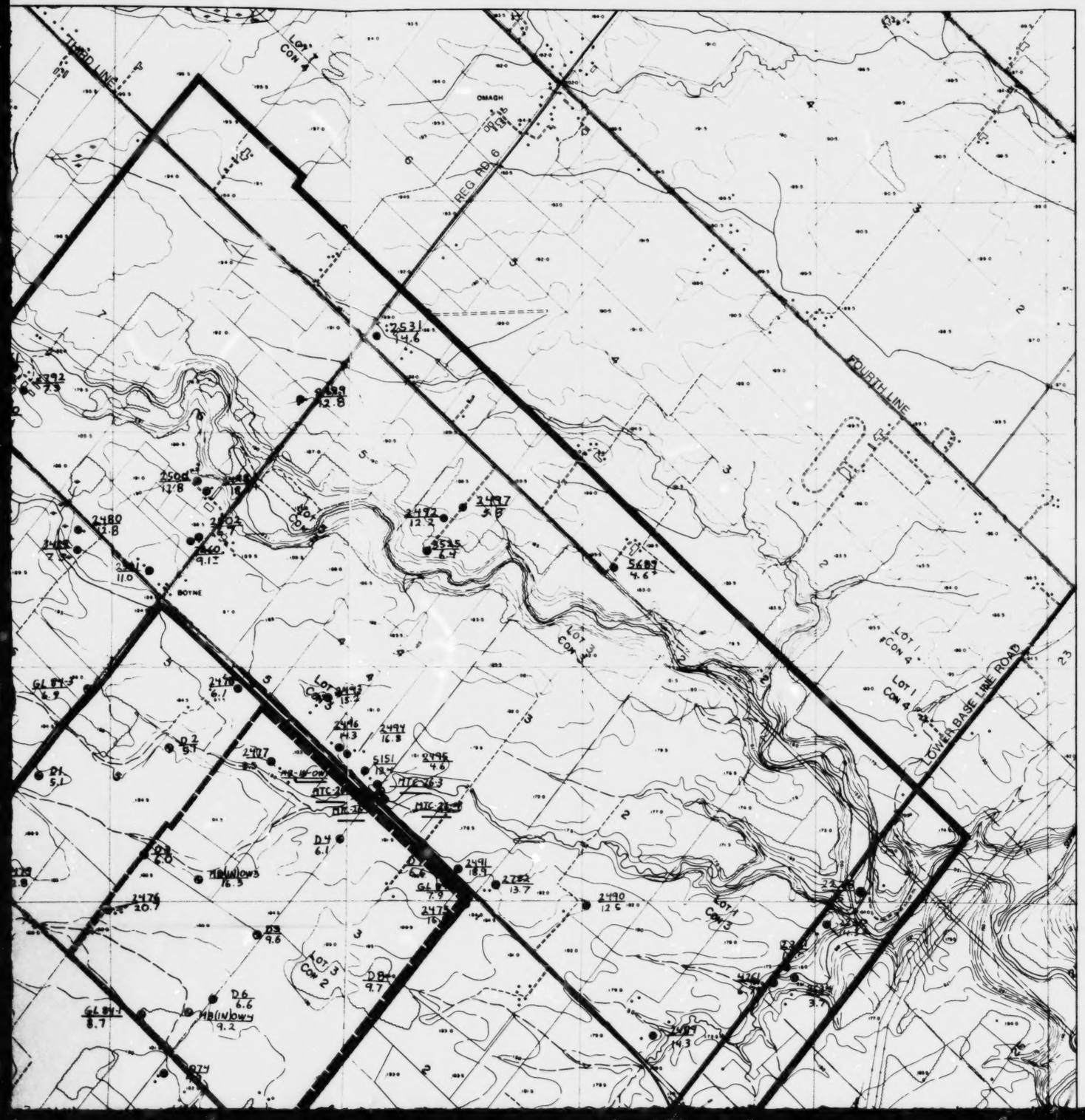
THIRD LINE
LOT 1 CON 1
REG RD 6
OMAGH
FOURTH LINE
LOWER BASE LINE ROAD
LOT 1 CON 4
LOT 3 CON 3
LOT 3 CON 2
LOT 1 CON 3
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MW20(4N)OW3

TREMAINE ROAD

BELL SCHOOL LINE

BRITANNIA ROAD

INDIAN CREEK

REG. RD. 22

LOT 1 CON 2

LOT 3 CON 2

LOT 11 CON 3

LOT 9 CON 1

LOT 1 CON 1

LOT 1 CON 2N

Town of Milton

City of Burlington

Contour Interval

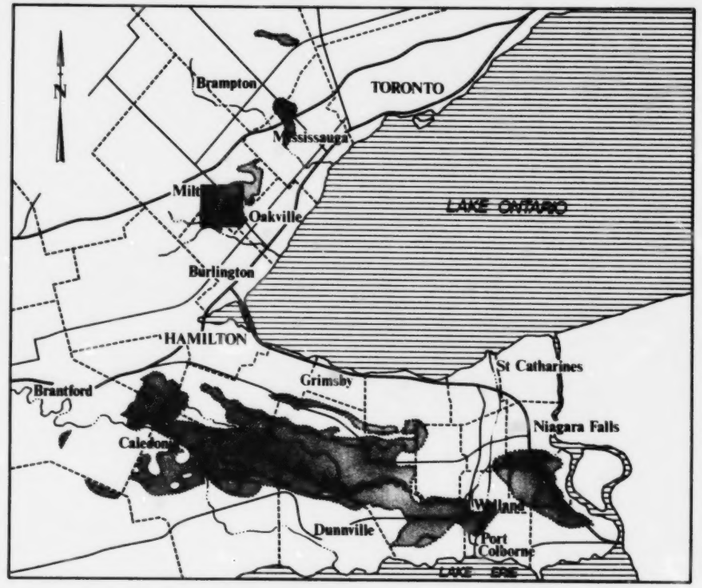
1:10 000 base mapping
Ministry of Natural Res

Proposed Acquisition Boundary
Phase 3B Acquisition Boundary
Site Vicinity Study Area Boundary

Key Map:

PI-1 North

Lots 3, 4 and 5; Concession II; Town of Milton; Parts of Lots 3, 4 and 5; Concession I; Town of Milton, formerly in the Township of Trafalgar



1000 feet 0 1000
500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Confining Layer Thickness

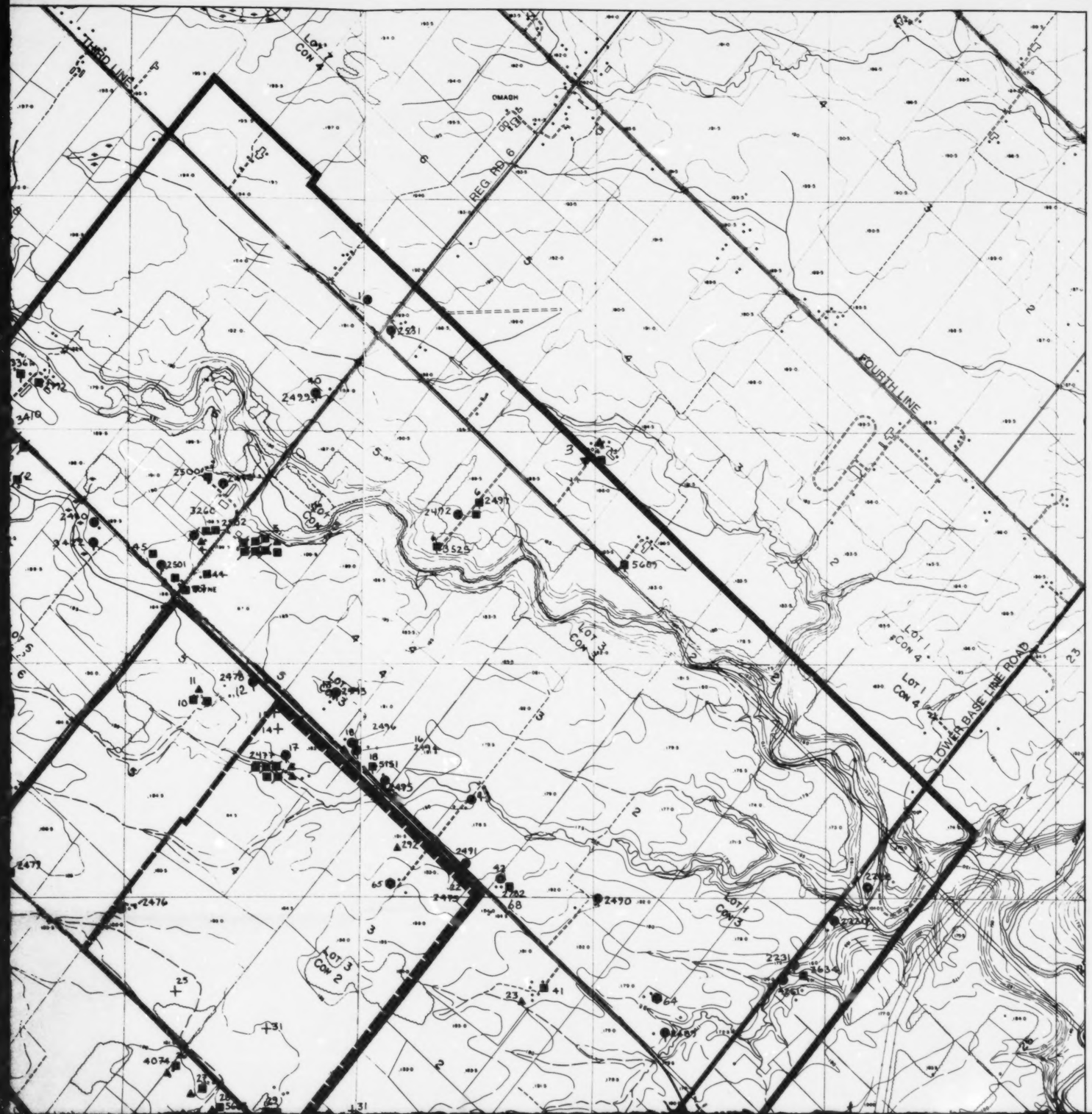
September 1985

FIGURE 7

Contour Interval in Metres

1:10 000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

HIGHWAY 401
SIXTEEN MILE CREEK
DERRY ROAD
CN
BRONTE ROAD
THIRD LINE
LOT 7 CON 4
OMAGH
REG RD 6
FIRST LINE
LOT 8 CON 1
LOT 5 CON 2
LOT 4 CON 3
TREMAINE ROAD
LOT 3 CON 2
LOT 11 CON 3



OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

- ●, ● DRILLED WELL COMPLETED IN OVERBURDEN, BEDROCK
- ■, ■ DUG OR BORED WELL COMPLETED IN OVERBURDEN, BEDROCK
- ● UNKNOWN WELL TYPE
- /, × UNUSED, ABANDONED WELL
- ▲ DUGOUT OR POND
- ▼ CISTERN
- \+ ADDITIONAL FIELD INFORMATION

NOTES:

No. 1-68 FIELD INTERVIEW INFORMATION: SEE SECTION 8.2 FOR DATA

No.'s >68 MINISTRY OF THE ENVIRONMENT WATER WELL RECORD NO.; SEE SECTION 8.1 FOR DATA

Proposed Acquisition Boundary
Phase 3B Acquisition Boundary
Site Vicinity Study Area Boundary

Key Map:

PI-1 North

Lots 3, 4 and 5; Concession II; Town of Milton; Parts of Lots 3, 4 and 5; Concession I; Town of Milton, formerly in the Township of Trafalgar

TREMAINE ROAD

BELL SCHOOL LINE

BRITANNIA ROAD

INDIAN CREEK

Town of Milton

City of Burlington

REG. RD. 22

LOT 3 CON 2

LOT 1 CON 3

LOT 1 CON 2

LOT 1 CON 1

LOT 1 CON 2N

LOT 1 CON 1N

Contour Interval

1:10000 base mapping

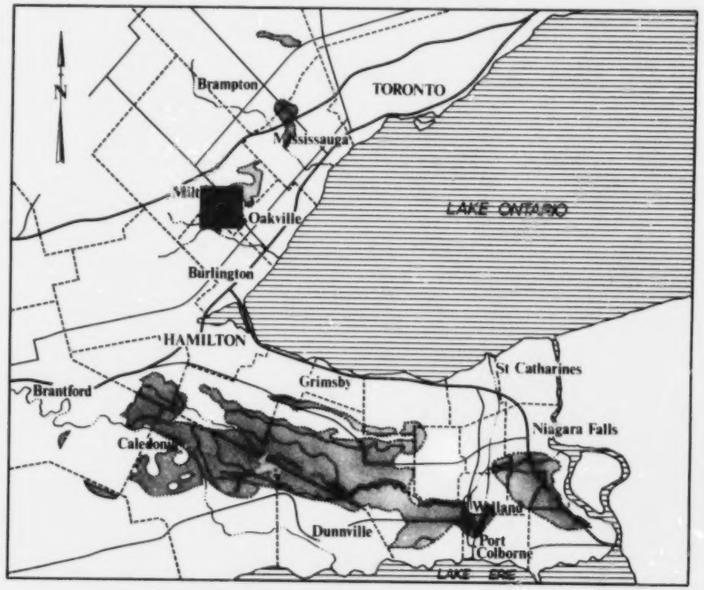
Ministry of Natural Resources

Proposed Acquisition Boundary
Phase 3B Acquisition Boundary
Site Vicinity Study Area Boundary

Key Map:

PI-1 North

Lots 3, 4 and 5; Concession II; Town of Milton; Parts of Lots 3, 4 and 5; Concession I; Town of Milton, formerly in the Township of Trafalgar



Contour Interval in Metres

1:10 000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

1000 feet 0 1000
500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Ground Water Use

September 1985

FIGURE 8

Number/
Numéro

8

SITE SELECTION PROCESS - PHASE 4A

TECHNICAL APPENDIX PI-13N

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS

A REPORT PREPARED FOR
ONTARIO WASTE MANAGEMENT CORPORATION
BY
GARTNER LEE ASSOCIATES LIMITED

THIS REPORT IS ONE OF EIGHT TECHNICAL APPENDICES DESCRIBING GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS OF THE CANDIDATE SITES. IT SUPPORTS THE COMPARATIVE EVALUATION STUDY WHICH IS ENTITLED "SITE SELECTION PROCESS; PHASE 4A, SELECTION OF PREFERRED SITE(S), GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS."

SEPTEMBER, 1985.

PROJECT 85-S18.3

Gartner Lee
Associates Limited

Gartner Lee Associates Limited

Consulting Engineering
Geologists
Biologists and
Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-477-8400
Telex-06-986278

September 19, 1985.

Dr. B.D. Mitchell,
Director of Corporate Planning
and Development,
Ontario Waste Management Corporation,
2 Bloor Street West,
11th Floor,
Toronto, Ontario,
M4W 3E2.

Attention: Mr. J.G. Micak,
Manager,
Environmental Projects.

Dear Dr. Mitchell:

Re: Site Selection Process - Phase 4A
Technical Appendix PI-13N - Geologic,
Hydrogeologic, and Geotechnical Considerations

Enclosed is our final report on the Geologic, Hydrogeologic, and Geotechnical Considerations at Candidate Site PI-13N. Similar reports prepared for each of the other candidate sites will form the basis for site comparisons.

Thank you for allowing our company to be of service.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

E.G. Anderson, P.Eng.,
Project Director.

KJG:jcm
Enclosures.

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STUDY TEAM

This report was prepared under the overall direction of Grant Anderson, P.Eng., Project Director and Gunther Funk, Project Manager. Major contributing authors were:

Hydrogeology	-	Kenneth Goff
Geology	-	Andrew Cooper
Geotechnics	-	Douglas Jagger, P.Eng.
Field Coordination	-	Norbert Woerns

1.0 INTRODUCTION

1.1 BACKGROUND

The Ontario Waste Management Corporation (OWMC) site selection process to locate facilities for treating hazardous wastes and disposing of the treated waste residues has been a phased process which began in 1981. Initial studies identified 261 hydrogeologic areas throughout southern Ontario which were grouped into six zones. Within the Golden Horseshoe, zone 1 and 2 lands were considered most favourable for facility siting. Twenty candidate areas were identified within the Zone 1 and 2 lands in the Golden Horseshoe in 1983. A total of 152 sites were identified in these twenty candidate areas in 1984 and this number was subsequently reduced in stages to sixteen potential sites and finally to eight candidate sites through the application of various constraints, screening processes, and ranking systems based on multidisciplinary factors. A more complete discussion of the site selection process is provided in the comparative evaluation study (GLAL 1985).

The present stage of study is the comparative assessment of the eight candidate sites. This Gartner Lee Associates Limited (GLAL) report documents and interprets available geologic, hydrogeologic, and geotechnical information for site PI-13N and serves as the data base for input to the site comparison study. The candidacy of this site is based on the potential development of a chemical treatment and/or incinerator facility. The Phase 3B preliminary assessment of this site was based primarily on existing data (GLAL 1984b).

Phase 4A investigations described in this report add significantly to the geologic, hydrogeologic, and geotechnical data base.

1.2 OBJECTIVES AND SCOPE

The objective of this study is to provide data for site PI-13N to accommodate comparisons with the other candidate sites. This objective has been met by undertaking investigations at this site to extend the data base and to increase levels of confidence in the existing data. The existing data base has been upgraded where possible and six boreholes have been drilled at selected locations on the site. Each of the boreholes has been continuously sampled to provide detailed geologic logs and soil samples. Boreholes were not instrumented and were plugged using grout on completion.

1.3 LOCATION

Site PI-13N is located in south-central Ontario in the Region of Halton. It is shown together with the seven other candidate sites in Figure 1 and is presented in greater detail on the maps in the map pockets at the rear of the report.

The site under consideration within this Technical Appendix covers approximately 170 hectares (ha) and includes Lots 3, and 4, Concession 6, Town of Milton, (formerly in the Township of Trafalgar), Regional Municipality of Halton. It is bounded on the east and west by the Sixth and Fifth lines respectively and is approximately 0.5 kilometres (km) south of Britannia Road West (Regional Road 6).

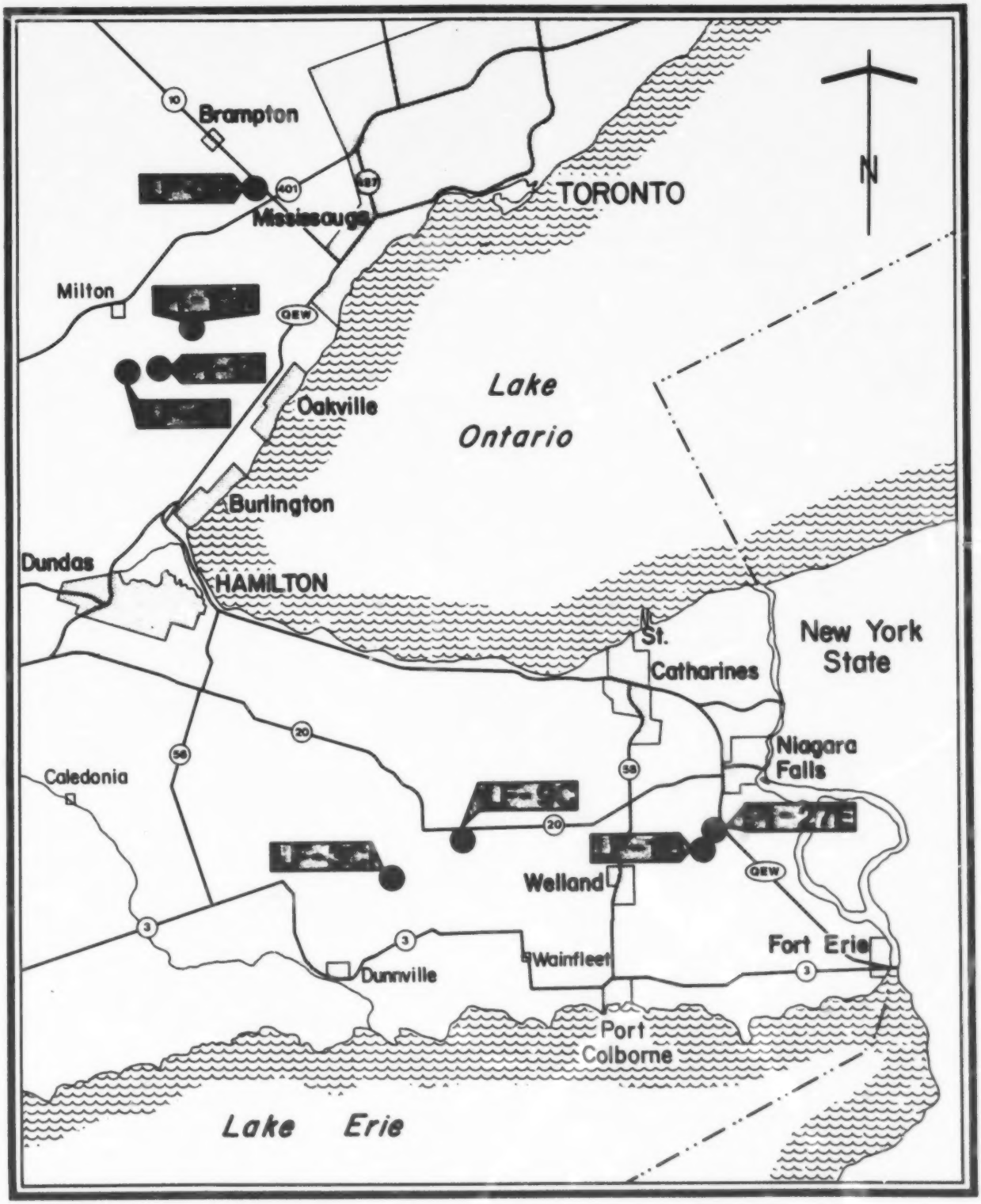


FIGURE 1 LOCATION OF CANDIDATE SITES

The site is located approximately 6 km southeast of the Town of Milton and is approximately 18 km northwest of Oakville. It is adjacent to Sixteen Mile Creek (Oakville Creek) and is roughly centered in a study area of about 2300 ha.

2.0 METHODOLOGY

The methodology employed in the collection, compilation, and interpretation of the information base presented in this technical appendix is described below and is illustrated in Figure 2.

2.1 DATA COLLECTION

The following sources of information were used:

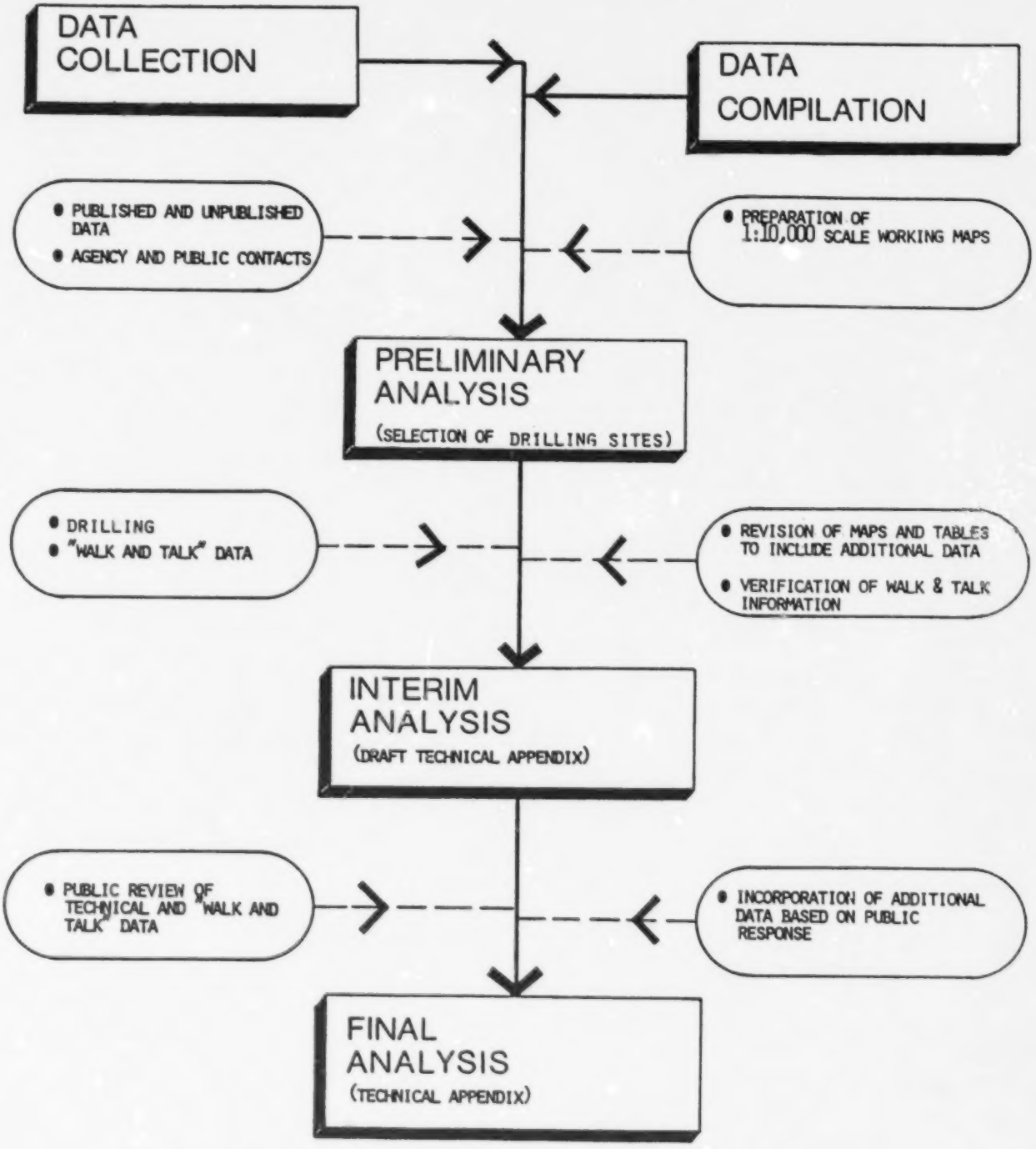
- water well and borehole records; published and unpublished reports, maps, and "open file" reports;
- interviews with government agency personnel and local residents; and
- onsite drilling and field survey results.

2.1.1 DATA BASE

Numerous reports and maps which contain both regional and local information on the geology and hydrogeology of the candidate sites were assembled during the earlier phases of the site selection process. Reports specific to this site are referenced in the text and are listed in Section 7.0. Data summaries are provided in Section 8.0

Figure 2

Methodology Flow Chart


DATA COLLECTION
DATA COMPILATION
• PUBLISHED AND UNPUBLISHED DATA
• AGENCY AND PUBLIC CONTACTS
• PREPARATION OF 1:10,000 SCALE WORKING MAPS
PRELIMINARY ANALYSIS
(SELECTION OF DRILLING SITES)
• DRILLING
• "WALK AND TALK" DATA
• REVISION OF MAPS AND TABLES TO INCLUDE ADDITIONAL DATA
• VERIFICATION OF WALK & TALK INFORMATION
INTERIM ANALYSIS
(DRAFT TECHNICAL APPENDIX)
• PUBLIC REVIEW OF TECHNICAL AND "WALK AND TALK" DATA
• INCORPORATION OF ADDITIONAL DATA BASED ON PUBLIC RESPONSE
FINAL ANALYSIS
(TECHNICAL APPENDIX)

Supplementary information was collected with the co-operation of government and other agencies. This information includes:

- copies of original water well records obtained from the Ministry of the Environment, and

- preliminary borehole records from the Town of Milton prepared by their consultants, Morrison Beatty Limited

These data are presented in Section 8.0. Copies of the data are on file.

2.1.2 INTERVIEWS

Additional information regarding site geology and water use was obtained during interviews with government agency personnel and local residents. The results of interviews are presented in the summaries prepared for agency meetings (by GLAL) and on resident interview forms (prepared by Ecologistics Limited). Meetings were held with the local public interest group made up of residents and other interested individuals who identified items of geologic and hydrogeologic interest. The summaries of meetings and the interview forms are on file. Local water use information summarized from the interview forms is tabulated in Section 8.2.

2.1.3 DRILLING AND FIELD SURVEY RESULTS

Borehole locations were selected based on preliminary analysis of available data and input from the public. Six boreholes were completed at selected locations on the site to confirm the expected character and continuity of the geologic

materials. Drilling and sampling procedures are presented in the document entitled "Phase 4A Drilling and Sampling Activities and Protocol" (GLAL 1984a) and the detailed methods employed during this study are summarized in Section 8.7.

The drilling program involved the collection of continuous samples from boreholes. These samples were photographed and described in the field, placed in suitable containers, and shipped to the Ontario Geological Survey in Toronto for storage. Split-spoon samples were taken at 1.5 m intervals to obtain standard penetration values and samples for moisture contents in order to carry out preliminary geotechnical assessments. Detailed borehole logs were prepared based on the field descriptions and on subsequent re-examination of the samples in storage. These logs are presented in Section 8.3 as part of the supporting information package.

2.2 DATA COMPILATION AND ANALYSIS

Data compilation and analysis has proceeded in a staged fashion according to the outline provided in Figure 2. In the initial work, information such as water well data was compiled in summary tables and illustrated on a series of working maps and cross-sections at a scale of 1:10 000. Maps included plots of:

- data point locations (all sources),
- surficial geology (Ontario Geological Survey reports), constraint mapping results from Phase 3B, and Ministry of the Environment maps and reports),

- bedrock elevation (water well data and borehole data),
- confining layer thickness (water well and borehole data),
- aquifer thickness (water well data),
- aquifer information (water well data), and
- anomalies such as granular zones (water well and borehole data).

These maps were used to establish the geographic distribution of existing data points and to expand (at a more detailed scale) the preliminary interpretation of geologic and hydrogeologic conditions as presented in the Phase 3B reporting (GLAL 1984b). Tentative drilling locations were then identified based on these analyses.

Following the selection of tentative drilling locations, GLAL personnel met with interested parties to present the results of the preliminary analyses and to discuss the purpose and scope of the Phase 4A program. Additional information on local geologic and hydrogeologic conditions was collected during these meetings. (Water use information provided by the public is incorporated in Section 4.2.3 of this report). Several shallow hand auger holes were dug during a field visit to the site. The locations are identified as 'field stations' in Figure 4 (in map pocket) and the descriptions of the geology at these locations are provided in Section 8.4. Landowners and tenants were also contacted at this time to obtain permission to drill on their

properties and proposed drill site locations were modified based on local inputs.

A separate data collection program commonly referred to as the "Walk and Talk" survey was undertaken. During this survey, individual residents were interviewed by personnel from Ecologistics Limited and the results were recorded in a questionnaire format. Among the multidisciplinary questions were several which were provided by Gartner Lee Associates Limited and which related specifically to water use. The collection of ground water information and related water use data was limited primarily to the site and to adjacent properties.

Additional water well locations were identified from mapping provided by Morrison Beatty Limited. Locations of these wells are shown in Figure 8.

With the completion of the drilling and public survey programs, the working maps were revised to incorporate the additional information that was collected. This technical appendix presents an interpretation of geologic, hydrogeologic, and geotechnical conditions at PI-13N to date. Draft copies of the data summaries were circulated to the local interest groups as a check on completeness and accuracy.

3.0 REGIONAL GEOLOGY AND HYDROGEOLOGY

The geology and hydrogeology of the Halton-Peel area are

summarized and discussed in reports prepared for the Ontario Waste Management Corporation (GLAL 1984b,c). This section is based on these reports and the reader is referred to them for more detail and for a complete list of references on which they are based.

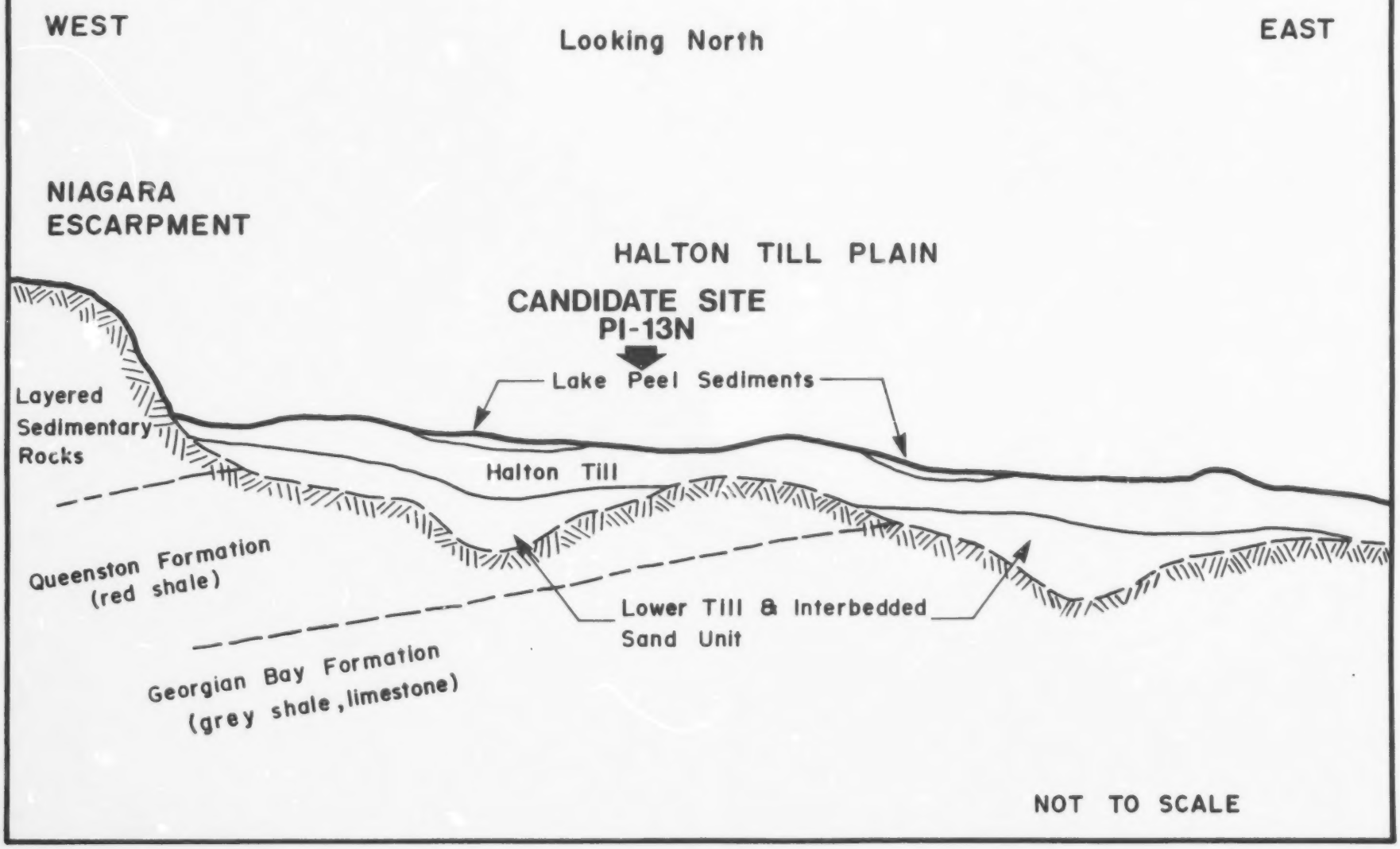
3.1 REGIONAL GEOLOGY

3.1.1 BEDROCK GEOLOGY AND OVERBURDEN THICKNESS

Bedrock in the south-central portion of Ontario consists of a series of sedimentary rock formations which dip gently to the southwest. The various rock formations are consequently exposed on the buried bedrock surface in a series of northwest-southeast trending bands which become progressively younger from northeast to southwest. Figure 3 shows the approximate location of Site PI-13N on a generalized cross-section from the Niagara Escarpment southeastward to Lake Ontario. In the Halton-Peel area the bedrock is the Georgian Bay Formation (grey shale and limestone) in the east and the Queenston Formation (reddish-brown shale) in the west. Generally, the bedrock surface is similar in shape to the present land surface and slopes gently from the Niagara Escarpment toward Lake Ontario. Bedrock usually occurs within 10 m of the ground surface and creek valleys are commonly eroded into the bedrock. Occasional buried valleys and depressions occur on the bedrock surface and the drift may be substantially thicker in these areas. At several locations, water courses have reoccupied portions of bedrock valleys (examples are Sixteen Mile Creek (Oakville Creek) and the Credit River). The Trafalgar Moraine located south of the site is the result of a temporary halt in the recession of the ice front.

FIGURE 3

Cross-Section Sketch Through Halton-Peel Area



3.1.2 QUATERNARY GEOLOGY

Good geologic exposures are infrequent and there has been limited published geologic survey work in the area to date. Available information is summarized and referenced in a previous OWMC report (GLAL 1984c).

Quaternary units are summarized in Figure 3. In view of the lack of detailed geologic studies in the area, only the uppermost till unit (Halton Till) and the Lake Peel sediments are referred to by formal names. The underlying deposits are collectively referred to as the 'lower till and interbedded sand unit' unit on a regional basis although subunits may be defined locally. From oldest to youngest the units are (1) a group of lower tills and granular deposits which directly overlie the bedrock, (2) the Halton Till, and (3) the Lake Peel glaciolacustrine sediments. The lower tills tend to be silty and sandy textured and sand deposits occur within and between them. It is possible that the Wentworth Till forms part of this unit (GLAL 1984c). The Halton Till is a clayey silt to silt till and the surficial Lake Peel sediments consist of an intermittent veneer of sands, silts, and clays.

The geologic events associated with these deposits began with a series of ice sheet advances and retreats which led to the deposition of the lower tills. Glaciolacustrine and/or glaciofluvial sands, silts, and clays were deposited between glacial advances and were preserved between the tills at some locations. The last ice advance occurred about 12 000 to 13 000 years ago and laid down the Halton Till. The character of this till suggests a fluctuating ice margin, possibly with a glacial lake in front of the ice. Several

subunits are known within the Halton Till and are occasionally separated by thin beds of silt, clay or sand (GLAL 1984c). A series of shallow, short-lived lakes were formed on the Halton Till during the final melting and retreat of the ice. These are responsible for a patchy veneer of sand, silt, and clay which is collectively known as the Lake Peel sediments. Since the final glacial retreat, the Halton Till and Lake Peel sediments have been subjected to weathering and erosion to produce the present landscape.

3.2 REGIONAL HYDROGEOLOGY

Figure 3 indicates geologic and hydrostratigraphic units which have been used in reports and publications for the Halton-Peel area (GLAL 1984b,c). Each of the units is discussed below in a regional context beginning with the bedrock and proceeding through the overburden from oldest to youngest.

The upper fractured portions of both the Queenston and Georgian Bay formations are sources of water supply. Regionally, they are considered poor aquifers as yields are generally low and water quality may be marginal to poor. However, where drift aquifers are not present, the bedrock is the only aquifer available. On a regional scale, ground water flow in the upper bedrock is toward Lake Ontario, however local flow patterns may be altered as a consequence of bedrock valleys and depressions.

Buried sand and gravel deposits in the region are summarized and mapped in previous reports (GLAL 1984b). Thin, discontinuous sand and gravel layers, sandwiched between

tills or directly above bedrock, occur in the study area and local water supplies are usually developed in the upper portion of the bedrock or in these sands and gravels.

The lower tills vary in texture from silt to silty sand. Sand and silt interbeds are common but vary in thickness, continuity, and hydraulic conductivity. Large diameter dug or bored wells which appear to be completed in this unit likely obtain water from granular interbeds.

The Halton Till is clayey silt to silt in texture and is a hydrostratigraphic unit of regional extent. Ground water movement through it is very slow because of its fine texture and low hydraulic conductivity.

Shallow dug and bored wells occasionally obtain water supplies from the surficial fractured portion of the Halton Till, however most wells extend to deeper granular deposits or to the bedrock. Alluvium may also provide water supplies to shallow dug and bored wells where such wells are completed in flood plains in the region.

4.0 SITE GEOLOGY AND HYDROGEOLOGY

The site-specific geology and hydrogeology of Site PI-13N takes into account the regional data and adds the new borehole information. In addition, data from field interviews are integrated into this analysis. Figure 4 (in map pocket)

provides locations of the cross-sections and the field data presented in this report.

Results from the GLAL borehole program at this comparative evaluation stage are used to confirm the geology and hydrostratigraphy and to evaluate the predictability and uniformity of subsurface conditions. Hydrogeologic discussions are based on the geology and on such other sources of information as water well and borehole records and water use data provided by local residents. Table 1 compares local geologic and hydrostratigraphic units for the site and vicinity. This table provides the framework for the discussions that follow, from the bedrock to surface.

TABLE 1: SUMMARY OF LOCAL GEOLOGIC AND HYDROSTRATIGRAPHIC UNITS

GEOLOGIC UNIT	HYDROSTRATIGRAPHIC UNIT	
HALTON TILL	CONFINING LAYER	FRACTURED ZONE (HALTON TILL)
		HALTON TILL
LOWER TILL AND INTERBEDDED SAND	LOWER TILL, AND INTERBEDDED SAND AQUIFER	
BASAL SAND	BASAL SAND AND	
BEDROCK	BEDROCK AQUIFER	
(QUEENSTON SHALE)		

4.1 SITE GEOLOGY

Six continuously sampled boreholes were drilled on Site PI-13N in 1984 by Gartner Lee Associates Limited. An additional three boreholes on the site and one adjacent to the site were also drilled by Morrison Beatty Limited in 1984. These boreholes along with the locations of water wells and cross-sections are provided in Figure 4 (in map pocket). Logs of boreholes and wells are included in Section 8.0 and cross-sections through the study area are presented in Figures 5 and 6 (in map pocket). Geologic descriptions are simplified for presentation and interpretive naming is provided. The following discussions are limited mainly to GLAL information.

4.1.1 TERRAIN

Site PI-13N is located on a portion of what is generally referred to as the Halton Till plain. Topography varies from gently undulating to flat except where it is dissected by stream erosion. These eroded valleys are major features on the landscape at the site. Elevations (above sea level) on the site range from about 193 m along the northeastern boundary to less than 180 m in the south and east corners. The site drains to East Sixteen Mile Creek which is also known as East Oakville Creek.

4.1.2 BEDROCK GEOLOGY AND DRIFT THICKNESS

GLAL boreholes which were cored into bedrock encountered reddish-brown shale with occasional grey-green zones and siltstone interbeds. The upper few metres of shale is extensively weathered. These descriptions are similar to those provided by Telford et al. (1976) and are considered to

indicate the Queenston Formation. This Formation is exposed in creek valleys immediately east and south of the site and at one location on site (eastern corner) where erosion has cut through the overburden. The locations of bedrock exposures are shown in Figure 7 (in map pocket). The bedrock surface is relatively flat with the exception of a shallow east-west bedrock depression which traverses the site. Elevations on the bedrock surface range from about 172 m to about 179 m and overburden thicknesses in the GLAL and Morrison Beatty boreholes range between about 6 m and 17 m.

4.1.3 LOWER TILL AND INTERBEDDED SAND UNIT

This unit occurs between bedrock and the Halton Till and ranges in thickness between 2.0 and 13.2 m (Boreholes GL5 and GL3 respectively). It is thinner in the north and south and thicker above the shallow bedrock depression which traverses the central part of the site in an east-west direction. The unit includes till and granular layers of varying thickness and stratigraphy. The till is generally of a silt to sandy silt texture and it ranges in thickness from about 2 to 10 m. In the north and south where the unit is thinner, it contains fewer and thinner sand interbeds, and till directly overlies the bedrock. It also shows a colour change from grey and greyish-brown to reddish-brown and increasing shale pebble content with depth.

A basal granular deposit was encountered in four of the six GLAL boreholes. It ranges in thickness from 0.8 to 4.1 m in Boreholes GL4 and GL6 respectively and appears to be limited to the bedrock depression which traverses the central portion of the site in an east-west direction. Textures range from fine to medium sand to silty sandy gravel and the

deposit is generally poorly sorted. This subunit changes in colour from grey to reddish-brown with depth and this change is usually accompanied by an increase in shale pebble c ntent. Water well records in the study area identify sand and gravel deposits directly on the bedrock (basal) as well as within the drift. In many cases the position of the deposits relative to the bedrock cannot be determined with the available data (Table 4), Section 8.1).

A sand deposit (1.3 m thick) was encountered in Borehole GL1 immediately below the Halton Till. The upper 4 m (approximately) of the 'lower till and interbedded sand unit' is very sandy in Borehole GL3 and it is possible that an upper sand layer is present beneath parts of the site immediately below the Halton Till.

4.1.4 HALTON TILL

The Halton Till was encountered in all GLAL boreholes. Colours range from brown to dark greyish-brown, textures range from clayey silt to silt. It is relatively uniform in texture except for sandy zones between 5 and 7 m (approximately) in Borehole GL2 and fine sand laminae at about 6 m in Borehole GL4.

The upper 1 to 2 metres of the till is intensively fractured and fractures are common to depths of about 2.5 m in most boreholes. Fracture frequency decreases rapidly with depth and fractures are infrequent below about 5 m. The deepest fracture was noted in Borehole GL4 at a depth of 9.0 m (Section 8.3). Grey carbonate infilling (with a clay-like texture) was occasionally observed in some fractures during logging.

4.1.5 ALLUVIUM

Alluvial deposits occur only in the eastern portion of the site adjacent to an intermittent stream. These deposits are thin, discontinuous, and are generally silty to sandy in composition.

4.1.6 DISCUSSION

The lower till and interbedded sand unit is texturally and stratigraphically variable. It contains numerous sand layers and is considered to be unpredictable and variable. The Halton Till is clayey silt to silt in texture, shows some variability in thickness, and is generally less than 7 m thick.

4.2 SITE HYDROGEOLOGY

The Phase 4A field work incorporates first-hand geologic descriptions and interpretations with the existing data base (primarily water well record and borehole information). Hydrogeologic analyses utilize the geology, the water well and borehole records, information provided by the public, and information supplied by researchers in similar hydrogeologic settings together with the experience of Gartner Lee Associates Limited staff. Descriptions of the hydrostratigraphic units, flow systems, ground water use, and potential contaminant pathways are presented in the following sections.

4.2.1 HYDROSTRATIGRAPHY

Three major hydrostratigraphic units occur at Site PI-13N. These identified in Table 1 and from bottom to top they are:

1) the bedrock and basal sand aquifers;

2) the lower till and interbedded sand aquifer, and
3) the confining layer.

The basal sand aquifer and the bedrock are considered to be in good hydraulic connection where they occur together. Hydrostratigraphic units with aquifer potential include the shale bedrock, the basal granular unit, and sand layers within the lower till and interbedded sand unit. The fractured and unfractured Halton Till constitutes the confining layer on the site.

4.2.1.1 Bedrock and basal sand aquifer

The bedrock is the most important source of ground water in the study area and is the sole aquifer where no sand and gravel deposits occur in the drift. Approximately 60% of wells reported by the MOE in the study area obtain water from the bedrock with the remainder relying on granular deposits. Supplies from the bedrock are generally low as more than half the wells produced 0.1 litres per second (L/s) or less with large drawdowns during testing (Table 4, Section 8.1).

The average hydraulic conductivity of the shale based on test pumping data from the water well records closest to the site (Section 8.1) and analytical techniques described by Walton (1962) and Ogden (1965) is about 8×10^{-7} m/s. This is similar to the geometric mean of about 5×10^{-8} m/s for several hydraulic conductivity tests in the Queenston shale at the Oakville landfill site. (GLAL 1981)

Several well records in the study area report granular deposits (sand and/or gravel) on the bedrock surface and water supplies have been developed from these deposits at

some locations. Details of water use are provided in Section 4.2.3.

4.2.1.2 Lower till and interbedded sand aquifer

This unit underlies the Halton Till in all the GLAL boreholes on the site. Till textures range from silt, to sandy silt, to silty sand. Sand interbeds range in thickness from a centimetre or less to a maximum of 1.3 m in Borehole GL1 where sand separates this unit from the Halton Till. An average hydraulic conductivity of 1×10^{-7} m/s is assigned to the 'lower till and interbedded sand aquifer' to reflect its overall silty character. This value is about within in the range of values for silt and silty sand supplied by Freeze and Cherry (1979).

Water well records in the study area indicate that several wells obtain supplies from sand layers within the till. Occasionally, records indicate the till as a source of supply; however, sand layers within the till are regarded as the more likely source.

4.2.1.3 Confining layer

The confining layer includes fractured and unfractured portions of the Halton Till. The 'lower till and interbedded sand aquifer' was not included because of its textural variability (sand layers). The confining layer varies in texture from silt to clayey silt and thicknesses range from about 3 to 7 m in the GLAL boreholes (Table 2).

Hydraulic conductivities for the unfractured Halton Till are based on a previous report for Site LF-4N (GLAL 1980). This report indicates a maximum hydraulic conductivity value

of $1x10^{-9}$ m/s from in situ slug tests and a value of $5x10^{-10}$ m/s using a triaxial laboratory apparatus. Based on these data, an average hydraulic conductivity of $1x10^{-9}$ is assigned to the unfractured Halton Till.

Thin, sandy zones and laminae which occur at depths between about 5 and 7 m in Boreholes GL2 and GL4 were not noted in other boreholes and are restricted to a relatively narrow depth interval. In view of their limited occurrence, these are considered not to constitute an important hydrostratigraphic unit.

The upper portion of the confining layer at Site PI-13N is heavily fractured to depths of 1 to 2 m and fractures are common to depths of about 4 m according to 1984 GLAL borehole logs. Test pit observations at Site LF-4N (GLAL 1980) indicate an absence of fracturing below a depth of about 2.5 m. Freeze and Cherry (1979) note that deposits of clayey or silty till and glaciolacustrine deposits in southern Ontario contain networks of hairline fractures which are essentially vertical and which are responsible for hydraulic conductivities one to three orders of magnitude greater than in unfractured materials. Based on this information, fracturing is considered to be responsible for a hydraulic conductivity difference of about two orders of magnitude between the fractured zone and the unfractured zone and a hydraulic conductivity of $1x10^{-7}$ m/s is applied to the fractured zone. An effective fracture porosity of 0.0001 is assigned to the fractured zone based on Desaulniers' (1980) data. Confining layer thicknesses for the site and the study area are shown on Figure 7 (in map pocket) for GLAL boreholes and for wells for which MOE well records are available. Confining layer

TABLE 2: SUMMARY OF CONFINING LAYER CHARACTERISTICS

BOREHOLE / PARAMETER	CONFINING LAYER SUBUNITS		CONFINING LAYER THICKNESS
	FRACTURED ZONE (HALTON TILL) (m)	UNFRACTURED ZONE (HALTON TILL) (m)	(m)
GL1	4.6	N/A	4.6
GL2	5.0	2.0	7.0
GL3	3.1	N/A	3.1
GL4	5.0	2.1	7.1
GL5	4.1	N/A	4.1
GL6	4.7	N/A	4.7
Average hydraulic conductivity (m/s)	$1x10^{-7}$	$1x10^{-9}$	
Average Porosity	0.0001	0.3	

Notes: N/A - not applicable

Unfractured porosity values are estimates of total intergranular porosity. The fracture porosity value is the effective porosity reported by Desaulniers (1982).

Porosity values in the unfractured materials reflect intergranular porosity. Additional fracture porosity is present in the fractured zone. The fractures are accompanied by increased hydraulic conductivities with the result that ground water can potentially move more rapidly along fractures.

thicknesses at water well locations were obtained from water well logs in Table 4 (Section 8.1) and are intended to reflect the thickness of the Halton Till. Some of the variability in the confining layer thickness in Figure 8 is due to differing levels of detail in some well logs.

4.2.1.4 Discussion

The confining layer is generally thin and averages about 5 m beneath the site. It is absent along the creek valley near the eastern site boundary where bedrock is exposed. In cases where the confining layer is less than 5 m thick, it consists entirely of fractured Halton Till. The 'lower till and interbedded sand aquifer' is not included in the confining layer because of the relatively common occurrence of sand layers within it.

4.2.2 GROUND WATER FLOW REGIME

Infiltration is the source of ground water and differences in hydraulic head provide the driving force for ground water flow systems. Site PI-13N is located in an area where the hydraulic gradients in the confining layer are downward. This condition is indicated by a water table which is close to the surface and by water levels in the underlying aquifer which are several metres below ground.

The water table occurs in the fractured zone and its shape is a reflection of topography. Fracturing and ground water flow diminish rapidly to the base of the fractured zone which extends to a depth of about 5 m on the site. The shallow flow system is potentially most active in the upper 1 to 2 m where fracture permeability is best developed. Flow in the fractured zone is greatest when the water table is

close to ground level and the saturated zone is thickest. Movement in the fractured portion of the confining layer is essentially lateral and rates and directions of flow are dependent on elevation differences in the water table. Under an average hydraulic conductivity of $1x10^{-7}$ m/s, a fracture porosity of 0.0001, and a lateral gradient of 0.01, the lateral flow rate in the fractured zone is estimated to be about $1x10^{-5}$ m/s or 300 m per year. Estimates of fracture flow rates are usually large relative to intergranular flow rates because of the large differences between intergranular and fracture porosity. Fracture flow rates are unrealistically large if the rates are interpreted as 'straight-line' flow pathways because fracture interconnections which do exist are usually complex and indirect.

In cases where the fracture zone completely penetrates the confining layer there is increased potential for infiltration through the confining layer and the amount of water available for lateral flow may be locally reduced.

Static water levels in wells completed in the upper bedrock and in sand and gravel deposits (below the confining layer) vary considerably in the study area, however static levels in dug and drilled wells adjacent to the proposed site are generally between 4 and 6 m below ground level. In estimating the downward gradient across the confining layer, the water table is assumed to be at ground level to represent a maximum head differential or driving force. The average gradient is estimated to be about 0.5 based on water levels reported in several wells adjacent to the site. Since this gradient is based on data from wells which terminate in the

upper bedrock and in the granular deposits, it may be larger than the gradient across the confining layer.

Estimates of vertical ground water flow rates in the confining layer are presented in Table 3. The unfractured confining layer is the most significant hydrostratigraphic unit retarding downward ground water movement as the rates of flow indicate.

A more accurate assessment of ground water flow rates through the confining layer using advection and diffusion calculations is contained in Appendix A of the report entitled "Site Selection Process; Phase 4A, Selection of Preferred Site(s), Geologic , Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

Ground water movement in the bedrock beneath the study area occurs primarily within the upper fractured zone where permeability is best developed. The direction of ground water flow in the upper bedrock appears to be toward East Sixteen Mile Creek which is incised into the shale. Deeper flow is likely southeast, toward Lake Ontario. Estimated ground water flow rates through the upper bedrock are considered to be about 50 m per year based on an average hydraulic conductivity of 8×10^{-7} m/s, a gradient of 0.002 and a fracture porosity of 0.001. Fracture flow rates should not be interpreted as 'straight-line' migrations since fracture interconnections are usually tortuous and may be indirect or poorly developed.

Since the basal granular deposits appear to be continuous along the east-west shallow bedrock depression which

traverses the site, it is considered that ground water flow in these deposits would be eastward toward East Sixteen Mile Creek which is incised through them.

4.2.3 GROUND WATER USE

Water use information is based on water well record data and on information collected from residents and landowners on the site and on directly adjacent properties.

TABLE 3: ESTIMATED VERTICAL FLOW RATES IN THE CONFINING LAYER

BOREHOLE	UNFRACTURED ZONE m/s	FRACTURED ZONE m/s
GL1	N/A	$5X10^{-4}$
GL2	$6X10^{-9}$	$2X10^{-5}$
GL3	N/A	$5X10^{-4}$
GL4	$6X10^{-9}$	$2X10^{-5}$
GL5	N/A	$5X10^{-4}$
GL6	N/A	$5X10^{-4}$

Notes: - N/A/ - Not applicable

- Multiply by $3.15x10^{7}$ for flow rates in metres per year.

- Thicknesses and selected hydraulic parameters for the confining layer subunits are provided in Table 2.

4.2.3.1 Availability

Water supplies for domestic, stock, and general agricultural purposes are obtained primarily from wells and cisterns and occasionally from ponds. Bottled water for drinking is reportedly used at two residences near the site and cisterns are supplied with trucked water at two other locations on the site. Water use information is summarized according to source in Figure 8 and is supported by summarized data in Table 5 (Section 8.2).

According to water well records, the bedrock and basal granular deposits are sources of water supply to the majority of the wells in the study area. There are no wells on record with the Ministry of the Environment on the site. Bedrock wells account for slightly more than half the wells in the study area. Reported pumping rates appear not to differ substantially between wells completed in the bedrock and the sand and gravel. Test pumping rates reported during well development are less than 0.1 litres per second (L/s) for more than half the wells and drawdowns are usually reported at, or within a few metres of the bottom of the well. Seven wells are reportedly 'dry' or have been abandoned due to low yields. Drilling contractors most frequently recommend pumping rates in the range of 0.03 to 0.15 L/s with pump settings between 10 and 20 m below ground. Bedrock wells usually obtain adequate supplies within the upper 4 to 8 m of the rock although a maximum penetration depth of 38 m is reported. The sand and gravel deposits identified in the well logs (Table 4, Section 8.1) follow no apparent pattern and in a few cases the driller has reported sand and gravel but has cased through it to obtain supplies from the bedrock.

Eighteen additional wells were reported during field information surveys; two drilled wells and one dug/bored well are on the site and five drilled wells and ten dug/bored wells are located on adjacent properties (Figure 8). The drilled wells are similar in depth to those reported in the water well summary (Section 8.1) and are used for domestic, stock and general agricultural purposes.

Rainwater cisterns are a common source of additional water supply. Most cisterns 'dry up' periodically during periods of low rainfall and several are maintained with trucked water. Dugouts and off-stream ponds are occasionally used for stock and agricultural purposes and one resident reportedly filters stream water as a source of supply.

4.2.3.2 Quality

Ground water quality from the bedrock and from deep sand and gravel deposits near the bedrock contact is generally reported as 'fresh'. Of approximately 100 water wells with MOE records in the study area, only three reportedly contain 'salty' or 'sulphurous' water. Based on the field survey information, water quality is generally reported as 'good/hard' and occasionally as containing iron and/or calcium. Water from three wells is limited to nonpotable uses reportedly for quality-related reasons. Water quality surveys conducted in the vicinity of the site (Funk 1979, GLAL 1981) indicate that ground water in the Queenston Formation is generally hard with elevated levels of dissolved solids, iron, bicarbonate alkalinity, and occasionally sulphate and chloride. Water quality from overburden sources is generally better than from the bedrock.

4.2.4 POTENTIAL CONTAMINANT PATHWAYS

In general, there are two hydrogeologic pathways by which contaminants could potentially leave this site; these are (1) natural pathways along ground water flow systems and (2) man-made pathways along such structures as abandoned and unplugged wells and tile drains. Natural pathways through the confining layer are characterized by low hydraulic conductivity and are discussed in the sections on Site Hydrogeology (4.2.1) and Ground Water Flow Regime (4.2.2).

Efforts have been taken to identify and locate all man-made structures such as water wells, gas wells, tile drainage systems, and excavations which may be located on site. These structures may act as pathways along which contaminants could move. For example, improperly sealed and abandoned wells which penetrate the confining layer could provide access to underlying aquifers. Shallow structures such as granular trench backfill and drainage tiles could provide an offsite pathway to surface water and shallow ground water.

The three water wells which are known on the site were identified through field interviews. They are in active use and are believed to penetrate the confining layer. No gas or oil wells are known on site and present information indicates that no portion of the site is tile drained.

Excavations are believed to be limited to the immediate vicinity of buildings on the site and no extensive corridors of permeable backfill materials were identified from the interview sheets.

5.0 GEOTECHNICAL CONSIDERATIONS

This section of the report provides a preliminary assessment of Site PI-13N from a soils engineering viewpoint. The geologic setting is described in detail in Section 4.0 of this report.

The geologic data base has been supplemented by standard penetration split spoon tests taken at approximately 1.5 m intervals in each of the six GLAL boreholes. The standard penetration (N) values have been used as a guide in estimating the relative density and consistency of the various soils. Shear strengths noted here are estimated from correlating the N values with empirical shear strength relationships. Moisture contents were also determined and are presented with the standard penetration test results on the geologic logs (Section 8.3).

A desiccated crust is associated with the surficial portion of the Halton Till. This crust varies in thickness from about 3.5 to 5 m with N values of 26 to 79 (blows per 0.3 m). Where clay textures are absent, the crust will behave as a compact to very dense cohesionless material. Where clay textures are present, it will behave as a very stiff to hard cohesive material with undrained shear strength generally in excess of 200 kPa. The in situ moisture content ranged from 10 to 17%.

There is a weaker stratum below the desiccated crust within the Halton Till. This stratum is about 1 to 3 m thick

and has a consistency of very stiff as indicated by the N values of 15 to 24 (blows per 0.3 m). These N values correspond to an undrained shear strength of 100 to 175 kPa. The soils were saturated with in situ moisture contents of 7 to 19%. A saturated sand layer was encountered in Borehole GL1 in the lower part of this stratum.

The 'lower till and interbedded sand unit' beneath the site is very dense with N values typically greater than 50. In situ moisture contents ranged from 5 to 13%.

A layer of sand and gravelly sand occurs immediately above the bedrock beneath portions of the site. This unit is very dense with N values exceeding 50. These materials are saturated with in situ moisture contents of 7 to 20%.

Preliminary assessments based on GLAL borehole data indicate that the geotechnical conditions are generally adequate for foundations and excavations provided that proper design is carried out. All geotechnical aspects will require further investigation during the Phase 4B work at the preferred site.

The allowable bearing pressure is generally adequate for light and medium weight structures with shallow strip or conventional pad footings. As a guide, an allowable bearing pressure of 300 kPa can be adopted for footings founded in the upper 2 m of the desiccated crust. For footings founded in the weaker stratum below the desiccated crust, the allowable bearing pressure is lower, possibly about 200 kPa as a guide. Settlement of such structures should not exceed tolerable limits.

For heavy structures, it will likely be necessary to transfer loads to the 'lower till and interbedded sand unit' where greater allowable bearing pressure occurs. Settlement within the 'lower till and interbedded sand unit' should not be a problem.

Temporary excavations can be safely carried out to considerable depth within the till materials at 1:1 side slopes with the following exceptions. Preliminary calculations indicate that excavations terminating within 1 m of the buried sand seam in Borehole GL1 and within 4 m of the lower sand layer (also in Borehole GL1) could be subject to heave. Where excavations intersect saturated sand layers, ground water control will be necessary.

In general, subsoils on the site have good handling and workability characteristics. Wet weather handling may require some special attention due to the clay content. Trafficability is also generally good except during wet weather.

6.0 SUMMARY

The site is located on the Halton Till southeast of the Town of Milton. The site is underlain by distinctive reddish-brown shale of the Queenston Formation. Overburden ranges between about 6 and 17 m in thickness and consists of a discontinuous basal granular unit, a lower till and interbedded sand unit, and the Halton Till. The lower till and interbedded sand unit is dense to very dense with silt to sandy silt texture and thin sand interbeds. The Halton Till

is clayey to silty in texture and ranges in thickness between about 3 and 7 m. The surficial fractured zone of the Halton Till is considered to have an average depth of about 5 m.

Three major hydrogeologic units beneath the site are, (1) the bedrock-basal sand aquifer, (2) the lower till and interbedded sand aquifer and (3) the confining layer. The Queenston shale is a regional aquifer and is the major source of domestic and farm supplies in the study area. Discontinuous basal granular deposits also provide supplies to several wells in the study area. Water quality in the bedrock and basal granular aquifer is generally reported as 'fresh', however some deeper bedrock wells report 'salty' water. Flow in this unit appears to be toward Sixteen Mile Creek (which is eroded into the bedrock). Deeper regional flow in the bedrock is probably southeastward toward Lake Ontario.

The confining layer consists of fractured and unfractured Halton Till. Thicknesses range between approximately 3 and 7 m and the average depth of the fractured zone is about 5 m. The confining layer is absent along the water course which is eroded into the bedrock in the eastern part of the site. Ground water flow in the saturated portion of the fractured zone tends to be lateral in response to water table gradients while flow through the confining layer tends to be vertically downward. Flow rates through the confining layer vary widely depending on the presence/absence of unfractured Halton Till.

Potential contaminant pathways off the site could occur along natural flow systems or along man-made conduits. Because the confining layer is generally thin and occurs

largely within the fractured zone, the natural flow system does not provide uniform containment. Man-made potential conduits through the confining layer appear to be limited to water wells, however foundations and excavations as well as the fractured zone could penetrate the confining layer at some locations.

Preliminary geotechnical evaluations indicate that subsurface conditions are generally competent and well suited for building foundations and excavations. Adequate allowable bearing pressures are available for light and medium weight structures. For heavy structures, it will likely be necessary to transfer the loads to the 'lower till and interbedded sand unit'. Temporary excavations can be safely carried out to considerable depth within till materials. Local ground water control will be necessary where saturated sand layers are intersected. Subsoils are considered to have good workability, handling, and trafficability characteristics; however, wet-weather conditions may require some special attention due to the clay content.

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8.0 SUPPORTING INFORMATION

8.1 SUMMARY OF WATER WELL DATA

8.2 SUMMARY OF SITE INTERVIEW (WALK AND TALK) DATA

8.3 BOREHOLE LOGS

8.4 FIELD STATION DESCRIPTIONS

8.5 SUPPORTING CALCULATIONS AND METHODS

8.6 GLOSSARY OF SELECTED TERMS

8.7 DETAILED FIELD METHODS

8.1 SUMMARY OF WATER WELL DATA

Copies of original Water Well Records obtained from the Ontario Ministry of the Environment (MOE) were used for the following data summary and are on file.

Water well locations are shown in Figure 4 (in map pocket).

Measurements, dimensions and quantities on the Water Well Records are in Imperial units but are presented in metric units in the summary.

Water well locations were plotted on 1:10 000 scale working maps for this project and elevations were re-estimated based on the more accurate contours on these maps. Well elevations are above sea level (ASL) and are estimated to the nearest metre.

Well records are arranged in numerical order.

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2206	DR. HURLEY CON. 2DSN, LOT 13, TOWN OF MILTON (Prev. TRAFALGAR TWP)	195	JUL 1953	15.2	18.3	FRESH	18.3	6.1	18.3	0.15	DOMESTIC	0.0	18.3	BLUE CLAY
												18.3	18.6	GRAVEL
2525	SORENSEN, MIKE CON. 4NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	189	NOV 1961	76.2	15.2	FRESH	15.5	6.1	--	0.08	DOMESTIC	0.0	3.7	TAN BROWN SOIL
												3.7	12.2	REDDISH CLAY
												12.2	15.2	RED SHALE
2526	SORENSEN, HARRY CON. 4NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	187	MAY 1964	76.2	9.4	FRESH	9.8	4.6	--	0.08	DOMESTIC	0.0	6.1	TAN BROWN SOIL
												6.1	9.4	RED SHALE
2527	SORENSEN, MIKE CON. 4NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	189	OCT 1965	76.2	9.1	FRESH	10.1	4.6	--	0.08	DOMESTIC	0.0	5.5	TAN BROWN SOIL
												5.5	9.8	RED SHALE
2528	FORD, R.F. CON. 4NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	192	SEP 1954	15.9	14.6	FRESH	15.2	3.0	--	0.08	DOMESTIC	0.0	7.6	CLAY
												7.6	13.7	SAND
												13.7	14.6	GRAVEL
												14.6	19.2	RED SHALE
2529	WATER FIELD, H.W. CON. 4NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	194	MAR 1956	15.9	19.5	FRESH	17.7	2.7	19.2	0.15	DOMESTIC	0.0	9.8	CLAY
												9.8	16.8	SAND, GRAVEL
												16.8	20.1	RED SHALE
2530	FLEMINGTON, N. CON. 4NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	193	APR 1958	15.9	10.7	FRESH	11.6	3.7	7.6	0.38	DOMESTIC	0.0	9.1	CLAY
												9.1	10.7	GRAVEL

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2532	OMAGH BALL CLUB CON. 4NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	194	AUG 1960	15.2	15.8 16.2	FRESH	16.2	3.7	16.2	0.15	PUBLIC	0.0 11.6 15.8	11.6 15.8 16.2	BROWN CLAY RED CLAY GRAVEL
2533	FORD, R.R. CON. 4NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	193	MAY 1966	16.8	16.5	FRESH	14.6	3.7	16.8	0.3	DOMESTIC	0.0 4.3 14.3	4.3 14.3 18.9	BROWN CLAY RED CLAY RED SHALE
2534	FEATHERSTONE, W. CON. 4NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	194	FEB 1953	15.2	17.4	FRESH	14.6	3.7	--	0.04	DOMESTIC	0.0 14.6	14.6 18.0	CLAY RED SHALE
2535	MCCANN, C. CON. 4NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	193	APR 1958	15.9	19.2	FRESH	16.2	4.9	18.3	0.08	DOMESTIC	0.0 10.7 15.8	10.7 15.8 19.8	CLAY SAND AND GRAVEL RED SHALE
2549	ENDECOT,ALLEN CON. 5NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	MAY 1964	76.2	10.4	FRESH	10.7	7.3	10.7	0.08	DOMESTIC	0.0 1.2 10.1	1.2 10.1 10.7	BROWN CLAY REDDISH SANDY CLAY AND BOULDERS RED SHALE
2550	SORENSEN, M. CON. 5NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	189	DEC 1957	15.9	23.3	Salty	14.6	8.5	9.1	0.3	STOCK	0.0 14.0	14.0 23.8	CLAY AND SOME GRAVEL RED ROCK

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2551	AHRENE, KARL, H. CON. 5NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	186	AUG 1961	76.2	6.1 9.1	FRESH	9.6	2.7	--	0.91	DOMESTIC	0.0 0.3 0.9 6.1 6.4 9.0	0.3 0.9 6.1 6.4 9.0 9.6	TOPSOIL BROWN CLAY RED CLAY SAND RED CLAY SAND
2552	MILLBAY INVESTMENTS CON. 5NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	189	MAR 1965	16.8	18.9	FRESH	10.7	9.1	17.7	0.15	DOMESTIC	0.0 0.9 10.7	0.9 10.7 20.1	FILL HARDPAN RED SHALE
2553	BEATY, HUGH CON. 5NS, LOT 3, TOWN OF MILTON (Prev. TRAFALGAR TWP)	189	OCT 1965	76.2	12.2	FRESH	12.5	4.6	--	0.38	DOMESTIC	0.0 4.6 11.0	4.6 11.0 12.2	TAN BROWN SOIL BROWN SANDY SOIL RED SHALE
2554	STEMMANN, PETER CON. 5NS, LOT 3, TOWN OF MILTON (Prev. TRAFALGAR TWP)	189	SEP 1967	76.2	10.4	FRESH	10.7	3.7	--	0.3	DOMESTIC	0.0 3.7 9.8	3.7 9.8 10.4	TAN BROWN SOIL GREY CLAY GREY SAND
2555	LA RICHE, DOUG CON. 5NS, LOT 4, TOWN OF MILTON (Prev. TRAFALGAR TWP)	190	MAY 1959	15.9	12.2	FRESH	10.5	5.5	14.6	0.08	DOMESTIC	0.0 0.3 7.9 10.1	0.3 7.9 10.1 14.6	CLAY LOAM BROWN CLAY GRAVEL CLAY RED SHALE
2556	MALONEY, T. CON. 5NS, LOT 4, TOWN OF MILTON (Prev. TRAFALGAR TWP)	186	JUL 1960	20.3	20.7	SULPHUROUS	11.6	1.8	20.7	0.08	DOMESTIC	0.0 0.3 3.4 10.7	0.3 3.4 10.7 21.9	TOPSOIL YELLOW CLAY RED CLAY AND GRAVEL RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2557	RUTHERFORD, H. CON. 5NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	192	MAR 1957	15.9	14.6	FRESH	14.5	1.5	13.7	0.08	DOMESTIC	0.0	9.1	CLAY
												9.1	12.8	CLAY AND STONES
												12.8	15.5	RED SHALE
2558	MCDOWELL, E. CON. 5NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	192	JUN 1959	76.2	12.2	FRESH	15.2	7.6	--	--	STOCK	0.0	12.2	RED CLAY AND BOULDERS
											DOMESTIC	12.2	15.2	SHALE
2559	BROWN, HUGH CON. 5NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	193	MAR 1967	76.2	14.0	FRESH	14.3	3.0	--	0.76	DOMESTIC	0.0	5.5	TAN BROWN SOIL
												5.5	12.2	REDDISH CLAY
												12.2	14.0	RED SHALE
2560	KELLY, JOHN CON. 5NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	193	OCT 1966	76.2	15.2	FRESH	18.3	15.2	16.8	0.38	DOMESTIC	0.0	4.6	BROWN CLAY
												4.6	15.2	BLUE CLAY
												15.2	18.3	COARSE SAND
2570	SEIDL, NICK CON. 6NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	192	MAY 1962	15.2	15.5	FRESH	14.9	3.7	14.6	0.38	DOMESTIC	0.0	5.5	BROWN CLAY
												5.5	12.8	GREY CLAY
												12.8	14.6	RED CLAY
												14.6	17.1	RED SHALE
2572	SEIDL, N. CON. 6NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	191	OCT 1953	15.2	19.8	FRESH	14.3	6.1	--	--	DOMESTIC	0.0	14.3	CLAY AND SOME GRAVEL AND SAND
												14.3	20.1	RED ROCK

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2573	SEIDL, N. CON. 6NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	189	OCT 1964	15.9	15.8	FRESH	12.2	4.6	23.8	0.08	DOMESTIC	0.0	5.5	GREY CLAY
												5.5	11.0	GREY CLAY AND BOULDERS
												11.0	11.6	RED CLAY
												11.6	23.8	RED SHALE
2574	SEIDL, N. CON. 6NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	189	JUL 1966	15.9	10.7	FRESH	PULLED	4.9	--	--	ABANDONED	0.0	6.4	BROWN CLAY
												6.4	10.7	GREY CLAY
												10.7	11.9	GREY CLAY AND FINE SAND
												11.9	12.2	RED CLAY
												12.2	20.7	RED SHALE
2575	SEIDL, N. CON. 6NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	191	JUL 1966	15.9	DRY	--	PULLED	--	--	--	ABANDONED	0.0	5.2	BUFF CLAY
												5.2	14.9	GREY CLAY AND SOME GRAVEL
												14.9	16.2	RED CLAY
												16.2	23.5	RED CLAY
2576	OWRC RIVER BASIN RESEARCH CON. 6NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	169	MAY 1966	17.4	1.5	FRESH	5.1	2.4	--	--	TEST HOLE	0.0	1.5	REDDISH TILL
												1.5	15.2	RED SHALE
2577	GALBRAITH, T. CON. 6NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	185	MAY 1952	15:2	16.8	FRESH	10.1	2.4	--	--	DOMESTIC	0.0	9.8	CLAY
												9.8	17.4	RED SHALE
2578	SWEETMAN, W. CON. 6NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	185	JUL 1956	15.9	36.0	SALTY	10.7	17.7	--	--	DOMESTIC	0.0	10.4	CLAY
												10.4	36.6	RED ROCK

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2579	SWEETMAN, C. CON. 7NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	186	JAN 1957	15.9	22.6	FRESH	17.7	8.5	21.3	0.08	DOMESTIC	0.0	9.1	CLAY
												9.1	15.8	CLAY AND COARSE SAND
												15.8	23.5	RED SHALE
2580	EDWARDS, HARVEY CON. 6NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	189	JUL 1961	15.2	16.2	FRESH	15.9	8.2	15.5	0.3	DOMESTIC	0.0	4.9	BROWN CLAY
												4.9	14.9	GREY CLAY AND GRAVEL
												14.9	16.5	RED SHALE
2581	ST. PIERRE, NEIL CON. 6NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	185	JAN 1967	76.2	11.6	FRESH	11.7	6.1	11.0	0.08	DOMESTIC	0.0	0.3	TOPSOIL
												0.3	3.0	BROWN CLAY AND BOULDERS
												3.0	9.8	RED CLAY
												9.8	11.3	SOFT SHALE
												11.3	11.7	HARD SHALE
2582	WOOLEVER, C.A. CON. 6NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	181	SEP 1967	13.3	18.3	FRESH	5.2	8.2	12.5	0.15	DOMESTIC	0.0	9.8	PREDUG
												9.8	20.1	RED SHALE
2583	BOLAN, JAMES CON. 6NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	193	MAR 1960	15.9	12.8 16.5	FRESH	12.3	4.0	19.8	0.15	DOMESTIC	0.0	6.1	BROWN CLAY
												6.1	10.7	GRAVEL AND CLAY
												10.7	19.8	RED SHALE
2584	DA SILVA, M.A. CON. 6NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	192	SEP 1961	76.2	9.1	FRESH	9.5	4.6	--	0.08	DOMESTIC	0.0	3.0	TAN BROWN SOIL
												3.0	7.6	REDDISH CLAY
												7.6	9.1	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2585	LAZAR, MICHAEL CON. 6NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	193	JUN 1962	76.2	11.6	FRESH	13.1	10.1	12.8	0.08	DOMESTIC	0.0	3.0	BROWN CLAY
												3.0	10.7	RED CLAY AND BOULDERS
												10.7	13.1	RED SHALE
2586	BOEHNERT, ALFRED CON. 6NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	193	JUN 1962	91.4	10.7	FRESH	11.6	7.0	10.7	0.08	DOMESTIC	0.0	7.0	PREDUG
												7.0	10.7	RED CLAY AND BOULDERS
												10.7	11.6	GRAVEL
												11.6		SHALE
2587	NEVEN'S CONSTRUCTION CON. 6NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	192	AUG 1962	15.9	DRY	--	11.3	--	--	--	--	0.0	0.3	TOPSOIL
												0.3	4.6	BROWN CLAY
												4.6	11.3	SOFT RED SHALE
												11.3	19.8	RED SHALE
2588	NEEDHAM, FRANK CON. 6NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	192	SEP 1962	76.2	10.7	FRESH	11.0	--	--	0.08	DOMESTIC	0.0	3.0	TAN BROWN SOIL
												3.0	7.0	REDDISH CLAY
												7.0	10.7	RED SHALE
2589	FORD, C. CON. 6NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	194	MAY 1963	76.2	11.9	FRESH	12.5	4.9	12.2	0.23	STOCK DOMESTIC	0.0	3.0	BROWN SANDY CLAY
												3.0	11.9	RED CLAY AND BOULDERS
												11.9	12.5	GRAVEL
												12.5	12.8	RED SHALE
2590	DA SILVA, M.A. CON. 6NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	192	MAY 1966	76.2	9.1	FRESH	9.4	3.7	--	0.08	DOMESTIC	0.0	4.9	TAN BROWN SOIL
												4.9	8.5	REDDISH CLAY
												8.5	9.1	GRAVEL WITH SAND
												9.1	--	RED SHALE
2591	SIMPSON, J. CON. 6NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	190	JUNE1958	15.9	9.8	FRESH	10.7	2.4	9.1	0.08	DOMESTIC	0.0	7.3	SANDY CLAY
												7.3	9.8	STONES AND GRAVEL
												9.8	19.8	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2592	SIMPSON, C.W. AND SON CON. 6NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	191	DEC 1958	15.9	17.7	FRESH	14.6	6.1	17.1	0.08	STOCK	0.0	0.6	TOPSOIL
												0.6	10.7	MUDDY CLAY
												10.7	13.7	MUDDY CLAY AND STONES
												13.7	19.8	RED SHALE
2593	FULLER, R. CON. 6NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	194	NOV 1961	76.2	8.5	FRESH	8.5	6.1	--	0.23	DOMESTIC	0.0	1.8	BROWN CLAY & BOULDERS
												1.8	8.5	REDDISH CLAY & BOULDERS
												8.5	--	SHALE
2594	LESLEY, GORDON CON. 6NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	193	MAY 1963	76.2	11.0	FRESH	12.1	6.1	11.6	0.08	DOMESTIC	0.0	2.4	BROWN CLAY
												2.4	11.0	RED SANDY CLAY & BOULDERS
												11.0	12.2	RED SANDY CLAY WITH LAYERS OF GRAVEL
												12.2	--	RED SHALE
2595	EAKINS, A. CON. 6NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	190	SEP 1964	76.2	10.4	FRESH	9.8	7.9	8.5	0.08	DOMESTIC	0.0	7.3	BROWN CLAY
												7.3	7.9	BOULDERS
												7.9	10.4	BLUE CLAY
												10.4	--	SHALE
2596	FLEMINGTON, N. CON. 6NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	193	OCT 1964	76.2	7.6	FRESH	11.3	7.6	10.7	0.08	DOMESTIC	0.0	0.6	TOPSOIL
												0.6	6.4	BROWN CLAY
												6.4	8.2	GRAVEL & BOULDERS
												8.2	11.3	BLUE SANDY CLAY
2614	NIELSEN, PETER CON. 7NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	SEP 1961	12.7	14.6 25.0	FRESH FRESH	11.0	4.9	27.7	--	DOMESTIC	0.0	0.9	TOPSOIL & BROWN SAND
												0.9	8.2	LIGHT BROWN CLAY
												8.2	10.7	BROWN HARDPAN
												10.7	27.7	RED SHALE
2615	SWEETMAN, C.C. CON. 7NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	190	AUG 1965	15.9	20.4	FRESH	16.5	7.0	22.9	0.08	DOMESTIC	0.0	7.0	DUG WELL
												7.0	19.2	CLAY & GRAVEL
												19.2	22.9	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2616	R. NIELSEN & SON NURSERIES LTD. CON. 7NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	SEP 1965	76.2	10.7	FRESH	14.6	6.1	--	--	DOMESTIC	0.0	4.6	TAN BROWN SOIL
												4.6	9.1	GREY CLAY
												9.1	14.3	RED SHALE
2617	COUTTA, F.A. CON. 7NS, LOT 3, TOWN OF MILTON (Prev. TRAFALGAR TWP)	186	MAR 1960	15.9	21.9	FRESH	9.1	10.7	25.9	0.08	DOMESTIC	0.0	7.3	BROWN CLAY
					24.9	FRESH						7.3	25.9	RED SHALE
2618	SCHOONHEY, ED., B. CON. 7NS, LOT 3, TOWN OF MILTON (Prev. TRAFALGAR TWP)	186	MAR 1960	15.9	26.8	FRESH	5.6	13.7	25.6	--	DOMESTIC	0.0	0.5	DARK BROWN TOPSOIL
												0.5	5.2	LIGHT BROWN CLAY
												5.2	28.7	HARD RED SHALE
2619	MACARTHUR, CAMPBELL CON. 7NS, LOT 3, TOWN OF MILTON (Prev. TRAFALGAR TWP)	186	APR 1961	15.9	15.2	FRESH	9.1	7.9	44.2	0.08	DOMESTIC	0.0	6.7	BROWN CLAY & STONES
												6.7	44.8	RED SHALE
2620	MACARTHUR, CAMPBELL CON. 7NS, LOT 3, TOWN OF MILTON (Prev. TRAFALGAR TWP)	187	MAY 1961	15.9	DRY	--	9.8 PULLED	--	--	--	ABANDONED	0.0	8.8	BROWN CLAY, STONES
												8.8	9.1	COARSE GRAVEL
												9.1	19.8	RED SHALE
2621	JAAP, HARDY CON. 7NS, LOT 3, TOWN OF MILTON (Prev. TRAFALGAR TWP)	196	AUG 1964	15.9	19.8	FRESH	7.2	10.7	29.0	0.08	DOMESTIC	0.0	5.2	CLAY & GRAVEL
					28.3							5.2	29.0	RED SHALE
2622	CHOW, BILL CON. 7NS, LOT 4, TOWN OF MILTON (Prev. TRAFALGAR TWP)	186	DEC 1960	76.2	14.3	FRESH	14.6	9.8	--	0.08	DOMESTIC	0.0	3.7	TAN BROWN SOIL
												3.7	14.3	REDDISH CLAY
												14.3	--	SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2623	FINNIE, S. CON. 7NS, LOT 4, TOWN OF MILTON (Prev. TRAFALGAR TWP)	189	DEC 1962	15.2	9.8 13.4	FRESH FRESH	9.3	5.5	21.9	0.08	STOCK DOMESTIC	0.0 4.9 7.3 8.5	4.9 7.3 8.5 21.9	BUFF CLAY BROWN CLAY RED CLAY RED SHALE
2624	CLANCY, A. CON. 7NS, LOT 4, TOWN OF MILTON (Prev. TRAFALGAR TWP)	189	MAY 1963	76.2	10.1	FRESH	10.7	6.1	10.4	0.15	DOMESTIC	0.0 1.2 10.1 10.7	1.2 10.1 10.7 --	BROWN CLAY RED CLAY & BOULDERS GRAVEL RED SHALE
2625	WRIGHT, G. CON. 7NS, LOT 4, TOWN OF MILTON (Prev. TRAFALGAR TWP)	185	APR 1967	76.2	13.4	FRESH	13.7	6.1	--	0.15	DOMESTIC	0.0 4.6 10.4	4.6 10.4 13.4	TAN BROWN SOIL REDDISH CLAY RED SHALE
2626	MCCHESNEY, DON CON. 7NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	179	MAY 1955	15.9	22.9	FRESH	11.6	7.6	7.6	0.08	DOMESTIC	0.0 11.0	11.0 24.1	CLAY RED ROCK
2627	TRAFALGAR SCHOOL BOARD CON. 7NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	SEP 1957	15.9	19.2	FRESH	16.5	6.1	18.3	0.08	PUBLIC	0.0 9.8 15.8	9.8 15.8 20.7	CLAY SAND & CLAY RED SHALE
2628	PERCY MERRY SCHOOL CON. 7NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	179	FEB 1964	76.2	14.0	FRESH	16.2	7.6	15.5	0.08	PUBLIC	0.0 5.5 10.7 12.5 15.2 16.2	5.5 10.7 12.5 15.2 16.2 --	REDDISH BROWN SANDY CLAY & BOULDERS REDDISH BLUE HARD CLAY & BOULDERS REDDISH BLUE SAND & BOULDERS REDDISH BLUE SANDY CLAY RED CLAY SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2629	OWRC RIVER BASIN RESEARCH CON. 7NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	182	MAY 1966	3.0	7.9	--	11.9	4.0	--	--	TEST HOLE	0.0	6.1	REDDISH BROWN STONY CLAY TILL
												6.1	10.4	GREY STONY CLAY TILL
														SCREEN 9.8M - 10.7M
												10.4	13.4	RED SHALE
2647	MCKEE, ED. CON. 8NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	OCT 1965	76.2	12.8	FRESH	13.1	6.1	--	0.08	DOMESTIC	0.0	3.7	TAN BROWN SOIL
												3.7	11.6	GREY CLAY
												11.6	12.8	RED SHALE
2650	FULLER, R. CON. 8NS, LOT 3, TOWN OF MILTON (Prev. TRAFALGAR TWP)	187	JAN 1957	15.9	13.4	FRESH	11.6	5.8	11.6	--	DOMESTIC	0.0	4.6	SILT
												4.6	7.9	GREY CLAY WITH PEBBLES
												7.9	14.9	LIGHT RED CLAY WITH GRAVEL
														SCREEN 11.6M - 12.8M
												14.9	--	RED SHALE
2651	KLAPACA, STAN CON. 8NS, LOT 3, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	MAY 1967	76.2	12.2	FRESH	12.5	6.1	--	0.08	DOMESTIC	0.0	4.6	TAN BROWN SOIL
												4.6	10.4	REDDISH CLAY
												10.4	12.2	RED SHALE
2654	CHAMBERLAIN, LORNE CON. 8NS, LOT 4, TOWN OF MILTON (Prev. TRAFALGAR TWP)	187	NOV 1959	76.2	17.1	FRESH	18.9	10.7	--	0.5	STOCK	0.0	9.1	BROWN CLAY
												9.1	10.7	REDDISH BROWN CLAY & BOULDERS
												10.7	18.9	SHALE
2655	TUCK, F.R. CON. 8NS, LOT 5, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	MAY 1959	15.9	18.3 19.8	FRESH	18.3	7.6	15.2	0.45	DOMESTIC	0.0	17.7	CLAY
												17.7	20.4	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
2657	ALDERSON,TOM CON. 8NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	JUN 1966	76.2	11.3	FRESH	11.6	6.1	11.3	0.08	DOMESTIC	0.0	0.6	TOPSOIL
												0.6	2.7	BROWN CLAY
												2.7	5.8	BROWN GRAVEL, BOULDERS
												5.8	7.9	BLUE CLAY
												7.9	11.6	HARD GRAVEL
2658	MADILL, NEIL CON. 8NS, LOT 7, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	NOV 1961	76.2	10.7	FRESH	17.1	10.7	15.2	0.1	DOMESTIC	0.0	4.6	BROWN SOIL
												4.6	10.7	REDDISH CLAY
												10.7	10.8	SAND & WATER
												10.8	13.7	REDDISH CLAY
												13.7	16.8	RED SHALE
2767	SAMUEL, ERNEST SAMSON FARMS CON. 7NS, LOT 7, TOWN OF MILTON (Prev. TRAFALGAR TWP)	186	NOV 1968	76.2	9.8	FRESH	11.3	6.7	10.4	0.45	DOMESTIC	0.0	3.7	BROWN SOIL
												3.7	9.8	REDDISH CLAY
												9.8	11.0	GRAVEL & WATER
2802	DR. PRIDDLE W. CON. 7NS, LOT 4, TOWN OF MILTON (Prev. TRAFALGAR TWP)	185	APR 1968	86.0	11.0	FRESH	12.2	2.7	11.6	0.23	DOMESTIC	0.0	0.3	DARK TOPSOIL
												0.3	1.8	SANDY CLAY
												1.8	11.0	BLUE CLAY
												11.0	12.2	GRAVEL CLAY & STONES
2805	GAUNT, G.V. CON. 6NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	182	APR 1968	15.9	4.9	FRESH	--	1.8	--	--	DOMESTIC	0.0	2.4	BROWN CLAY
												2.4	5.8	DULL RED CLAY
												5.8	11.0	RED SHALE
3068	SIMPSON, J. CON. 6NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	190	APR 1969	76.2	4.9 6.7	FRESH FRESH	9.1	0.6	--	--	DOMESTIC	0.0	0.6	TOPSOIL
												0.6	4.9	BROWN CLAY & STONES
												4.9	6.7	BROWN SAND & GRAVEL
												6.7	7.9	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
3210	MCKEE, A. CON. 6NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	186	JUL 1969	76.2	5.5 11.3	FRESH FRESH	11.6	5.5	11.6	--	DOMESTIC	0.0 0.3 3.7 10.1	0.3 3.7 10.1 11.6	BROWN TOPSOIL BROWN CLAY, STONES BROWN GRAVEL WITH HARDPACKED SAND RED SHALE
3214	SIMPSON, C.W. CON. 6NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	190	SEP 1969	76.2	7.0	FRESH	8.2	3.0	7.9	--	DOMESTIC	0.0 0.3 4.9 7.9	0.3 4.9 7.9 --	BROWN TOPSOIL BROWN CLAY, STONES, HARD BROWN GRAVEL, SAND, HARDPACKED RED SHALE
3248	WELLS, GEORGE CON. 5NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	192	OCT 1969	76.2	8.2	FRESH	8.5	3.0	7.9	--	DOMESTIC	0.0 0.6 8.2	0.6 8.2 8.5	BLACK TOPSOIL BROWN CLAY, STONES BROWN SAND
3495	PARIDDLE, W. CON. 7NS, LOT 4, TOWN OF MILTON (Prev. TRAFALGAR TWP)	185	JUN 1970	86.2	9.4	--	9.4	5.2	12.2	0.4	DOMESTIC	0.0 5.2 7.6 9.4	5.2 7.6 9.4 13.4	BROWN CLAY BLUE CLAY, STONES CLAY, STONES, HARDPAN RED SHALE
3513	MORLEY, L.S. CON. 7NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	AUG 1970	76.2	9.8	FRESH	11.3	8.2	--	--	DOMESTIC	0.0 0.3 4.0 5.2 5.8 6.7 7.0 9.1 9.8 10.1 11.3	0.3 4.0 5.2 5.8 6.7 7.0 9.1 9.8 10.1 11.3 --	TOPSOIL BROWN CLAY, PACKED GREY CLAY, GUMBO LIKE GREY CLAY WITH SAND LAYERS BROWN CLAY, STONES, HARD PACKED BLUE STONES, FLAT STONE LAYER GREY CLAY, STONES, HARD PACKED GREY CLAY, GUMBO GREY SILT GREY GRAVEL, SILT BLUE CLAY

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
3738	FORD, CLARENCE CON. 7NS, LOT 7, TOWN OF MILTON (Prev. TRAFALGAR TWP)	191	NOV 1971	76.2	16.5	FRESH	17.1	6.1	16.5	--	DOMESTIC	0.0	0.3	BROWN FILL
												0.3	0.5	BROWN TOPSOIL
												0.5	1.2	BROWN CLAY, SAND, SOFT
												1.2	9.8	GREY CLAY, STONES, PACKED
												9.8	15.5	BROWN CLAY, STONES, HARD PACKED
												15.5	17.1	BROWN COARSE SAND, POROUS
3994	TIMM ENTERPRISES CON. 7NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	JAN 1972	76.2	7.0	FRESH	9.8	6.7	9.1	--	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	4.6	BROWN CLAY, DENSE
												4.6	7.0	GREY CLAY, SOFT
												7.0	8.5	BROWN CLAY, DENSE
												8.5	9.8	MEDIUM SAND, LOOSE
												9.8	--	SAND STONES, PACKED
4051	WILLIAMSON, A.C. CON. 5NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	185	MAY 1972	76.2	4.0 7.0	FRESH FRESH	7.6	3.7	8.2	0.08	DOMESTIC	0.0	3.4	BROWN CLAY
												3.4	3.7	BROWN SAND
												3.7	4.0	RED SHALE, VERY HARD
												4.0	4.6	RED SHALE, BROWN CLAY, SOFT
												4.6	8.2	RED & GREEN SHALE, VERY HARD
4122	MCLEA, W. CON. 8NS, LOT 3, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	NOV 1972	76.2	13.7	FRESH	14.0	4.6	14.0	0.4	DOMESTIC	0.0	0.5	BLACK TOPSOIL
												0.5	2.1	BROWN SAND, SOFT
												2.1	2.7	BROWN CLAY, SOFT
												2.7	6.7	GREY CLAY, BLUE CLAY, HARD TO SOFT
												6.7	9.4	BROWN CLAY & STONES, HARD PACKED
												9.4	10.1	BROWN SAND, STONES
												10.1	11.6	RED CLAY, HARD
												11.6	14.0	RED SHALE, GREEN SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
4139	TOWN OF OAKVILLE CON. 7NS, LOT 6, TOWN OF MILTON (Prev. TRAFALGAR TWP)	185	OCT 1972	76.2	14.0	FRESH	15.5	4.6	15.2	0.08	DOMESTIC	0.0	0.3	BLACK TOPSOIL
												0.3	1.8	GREY CLAY, DENSE
												1.8	4.6	BROWN CLAY, HARD
												4.6	5.5	GREY CLAY WITH SAND LAYERS, SOFT
												5.5	7.9	BROWN CLAY, HARD PACKED
												7.9	11.0	BROWN CLAY, SAND
												11.0	13.1	GREY CLAY, HARD PACKED
												13.1	14.0	BLUE CLAY, SOFT
												14.0	15.5	BROWN SAND, MUCK
4479	CHOW'S FARM CON. 7NS, LOT 4, TOWN OF MILTON (Prev. TRAFALGAR TWP)	186	APR 1974	76.2	15.5	FRESH	16.2	0.6	4.3	0.4	DOMESTIC	0.0	0.3	BROWN TO BLACK TOPSOIL
												0.3	1.2	YELLOW SAND, LOOSE
												1.2	7.3	GREY CLAY STONES, PACKED
												7.3	13.7	RED CLAY, BROWN CLAY, GREY CLAY, STONES, HARD PACKED
												13.7	16.2	RED SHALE, GREEN SHALE
4492	LISTER, L. CON. 7NS, LOT 4, TOWN OF MILTON (Prev. TRAFALGAR TWP)	186	DEC 1973	76.2	7.0	FRESH	13.7	4.6	13.1	0.13	DOMESTIC	0.0	0.3	FILL
												0.3	0.9	BROWN MEDIUM SAND, SOFT & MOIST
												0.9	6.7	BLUE CLAY, GREY CLAY, STONES SOFT & HARD
												6.7	7.0	RED COARSE SAND, LOOSE
												7.0	8.8	RED SAND, BROWN CLAY, HARD PACKED
												8.8	13.7	GREY CLAY, SILT, STONES
4615	DAY, R. CON. 5NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	OCT 1974	15.9	10.4	FRESH	9.1	4.6	18.3	0.08	DOMESTIC	0.0	0.3	TOPSOIL
												0.3	9.1	BROWN CLAY, STONES
												9.1	21.3	RED SHALE
4656	DAY, R.B. CON. 5NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	DEC 1974	--	10.1	FRESH	-- PULLED	4.9	17.4	0.08	ABANDONED	0.0	4.6	BROWN CLAY
												4.6	6.4	BROWN SANDY CLAY
												6.4	10.1	GREY, CLAY
												10.1	12.2	GREY SANDY CLAY
												12.2	18.6	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
4733	LAING, D. CON. 8NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	186	JAN 1975	15.9	14.0	FRESH	9.8	6.4	15.8	--	DOMESTIC	0.0	3.7	BROWN CLAY
												3.7	8.2	GREY CLAY
												8.2	9.8	RED CLAY
												9.8	16.5	RED SHALE
5197	MARSHALL, COLIN CON. 5NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	185	MAR 1978	76.2	9.8	FRESH	12.2	7.9	--	--	DOMESTIC	0.0	5.5	BROWN CLAY, SANDY, HARD
												5.5	8.5	BROWN CLAY, STONES, HARD
												8.5	9.1	RED SHALE, BOULDERS
												9.1	11.9	BLUE SHALE, HARD AND SOFT STRINGERS
												11.9	12.2	BLACK SHALE, HARD
5287	MOLONY, T. CON. 5NS, LOT 4, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	AUG 1978	76.2	6.1	FRESH	8.5	2.4	8.2	0.2	DOMESTIC	0.0	6.1	BROWN CLAY, SAND
												6.1	7.9	BROWN FINE SAND, SILT
												7.9	8.5	BROWN SAND, GRAVEL, STONES
5336	MARTIN, R.S. CON. 8NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	185	AUG 1978	76.2	8.8	FRESH	9.1	--	8.5	0.23	DOMESTIC	0.0	1.5	BROWN CLAY, LOOSE
												1.5	8.5	GREY CLAY & STONES, LOOSE
												8.5	9.1	RED CLAY(MEDIUM HARD)
												9.1	--	RED SHALE
5347	LESLIE, MARION CON. 7NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	191	MAR 1982	15.9	22.3	FRESH	15.8	7.6	22.3	0.08	DOMESTIC	0.0	9.1	BROWN SANDY CLAY, LOOSE
												9.1	15.2	GREY CLAY, FINE GRAVEL & BOULDERS, LOOSE
												15.2	15.8	GREY FINE SAND & GRAVEL, LOOSE
												15.8	22.9	RED SHALE, HARD
5348	CHOMA, WM. P. CON. 7NS, LOT 1, TOWN OF MILTON (Prev. TRAFALGAR TWP)	191	MAR 1979	15.9	15.2	FRESH	15.2	7.6	14.6	0.23	DOMESTIC	0.0	4.6	LOOSE BROWN SANDY CLAY
												4.6	9.4	LOOSE GREY CLAY
												9.4	14.9	HARD GREY GRAVELLY CLAY & BOULDERS
												14.9	15.2	LOOSE GREY FINE GRAVEL & SAND
												15.2	16.8	LOOSE GREY CLAY
5662	DAVIS WELDING CON. 5NS, LOT 2, TOWN OF MILTON (Prev. TRAFALGAR TWP)	186	APR 1981	76.2	7.9	FRESH	8.5	2.4	--	0.6	DOMESTIC	0.0	0.3	BROWN TOPSOIL
												0.3	4.1	BROWN CLAY, STONES
												4.1	7.9	GREY & RED CLAY, STONES
												7.9	8.5	RED SHALE

TABLE 4, SUMMARY OF WATER WELL DATA

Site: PI-13N

MOE WELL No.	OWNER NAME & LOCATION	GROUND ELEV'N (m ASL)	DATE DRILLED MN YR	WELL DIAM (cm)	WATER FOUND (m)	WATER QUALITY	CASING DEPTH (m)	STATIC LEVEL (m)	PUMPING LEVEL (m)	PUMP RATE (L/s)	WATER USE	FROM (m)	TO (m)	MATERIALS DESCRIPTION
5805	??? CON. 2DNS, LOT 22, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	MAR 1981	15.9	10.4 16.8	FRESH FRESH	12.5	2.4	13.7	0.8	DOMESTIC	0.0 0.3 5.2 10.7 11.6	0.3 5.2 10.7 11.6 19.8	BROWN TOPSOIL BROWN CLAY WITH RED STREAKS GREY CLAY RED CLAY WITH SANDY GRAVEL RED SHALE
5837	JAMES, T. CON. 7NS, LOT 3, TOWN OF MILTON (Prev. TRAFALGAR TWP)	188	APR 1992	15.9	39.0 41.1	FRESH FRESH	12.8	10.3	--	0.15	DOMESTIC	0.0 12.2	12.2 42.7	RED CLAY, STONES, FIRM RED SHALE WITH LIMESTONE SEAMS, FIRM & HARD
6064	CASCIOLI, DANY CON. 7NS, LOT 7, TOWN OF MILTON (Prev. TRAFALGAR TWP)	192	JUL 1983	15.9	28.9	FRESH	28.3	3.4	21.3	1.06	DOMESTIC	0.0 4.6 15.8 19.5 28.3	4.6 15.8 19.5 28.3 33.5	BROWN CLAY, LOOSE BROWN SANDY CLAY & GRAVEL, LOOSE BROWN SAND & GRAVEL, LOOSE BROWN CLAY, LOOSE BROWN SANDY CLAY & GRAVEL, LOOSE

8.2 SUMMARY OF SITE INTERVIEW (WALK AND TALK) DATA

Water use data from Ecologistics Limited field interview (Walk and Talk) forms is presented in Figure 8 (in map pocket). Water use data were collected from onsite and adjacent properties. A copy of the water resources form used in the field interviews is attached at the end of this section.

Water use data are augmented with information collected by Gartner Lee Associates Limited staff during discussions with local interest groups and individuals. Additional wells identified from mapping provided by Morrison Beatty Limited are located in Figure 8 and are included in Table 5.

Deeper drilled wells are considered to terminate in bedrock where supporting evidence is available.

Although most of the information was provided in Imperial units, it has been converted to metric units for uniformity with the remainder of the report.

Interview numbers are related to identifications assigned by Ecologistics Limited during the collection of these data.

Copies of the interview forms are on file.

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site PI-13N Sheet 1 of 8

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
1	Mr. Stewart Scott	5 Town of Milton (formerly Trafalgar Twp.)	7	609				Ponds for stock watering location uncertain No well use reported
2	Mr. Daniel Jones	4 Town of Milton (formerly Trafalgar Twp.)	6	140-2	✓			Drilled well (no MOE record) - 24.4 to 27.4m (80 to 90 ft.) deep, supplies household - 20 grains of hardness Pond for stock/irrigation
3	Mr. & Mrs. W.J. & N. Rowe	3 Town of Milton (formerly Trafalgar Twp.)	7	99-1		✓		Bored well (no MOE record) - 15.8m (52 ft.) deep - well dry on 2 occasions when extra people lived in the house. - hard water - supplies household
4	Mr. & Mrs. A. Glinski	3 Town of Milton (formerly Trafalgar Twp.)	7	128-1	✓		✓	Drilled well (no MOE record) - 38.4m (126 ft.) deep - high calcium do not drink water, supplies household Cistern supplies household Bottled water
5	Mr. & Mrs. G. Juengel	3 Town of Milton (formerly Trafalgar Twp.)	7	6-1	✓	✓	✓	Drilled well (MOE Well 2618) - 27.4m (90 ft.)deep - poor yield, not used Bored well (no MOE record) - 9.1m (30 ft) deep - non-drinking water uses - i.e. laundry (cont'd)

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site PI-13N Sheet 2 of 8

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
5	(continued)							- runs dry in June every year, comes back in December. Cistern used for drinking water (clean, soft) - 2275 L (500 gal.) capacity Stream used for non-drinking purposes (well filled with stream water).
6	Mr. Chris Austin	3 Town of (formerly Twp.)	7 Milton Trafalgar	237-1	✓		✓	Drilled well (MOE Well 2617) - 26.2m (86 ft.) deep - good quality, hard, used for drinking - well reacts within 2-3 days of rainfall - well goes dry regularly recovers within 3/4 hours - water level at 7m (23ft.) Cistern supplies household

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site PI-13N Sheet 3 of 8

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
7	Mr. & Mrs. H. Jaap	Pt.3 Town of (formerly Twp.)	7 Milton Trafalgar	234-1	✓		✓	Drilled well (MOE Well 2621) - 28m (92 ft.) deep. - very good quality, hard,tasteless, used for drinking - water level drops in summer with excess use, never runs dry Cistern collects rainwater household uses
8	Mr. & Mrs. C. Sweetman	Pts.2 & 3 Town of (formerly Twp.)	7 Milton Trafalgar	52-2	3			Drilled wells (MOE wells 2578, 2579,2615). - 1956 salty, inadequate supply - 0-10.4m clay 10.4-26.6m red shale - 1957 inadequate supply 0-9.1m clay 9.1 - 15.8m clay,m.snd. 15.8-23.5m red shale - 1965 inadequate supply 0-7.9m previously drilled 7.9-19.2m clay, gravel 19.2-22.9m red shale Stream water used for drinking - water diverted to 30m (100ft.) trench. Trench filled with - 15m crushed stones and 15m sand After flowing through trench, water held in 3.3m deep concrete holding tank and pumped to house. Drinking water run through U.V. charcoal filter system

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site PI-13N Sheet 4 of 8

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s	Cistern	Remarks
8	(continued)							- water hard (27 grains) Stream water also used to irrigate crops and to fill farm pond.
9	Mr. George Jellaczyc	2 Town of Milton (formerly Trafalgar Twp.)	6	58-2		✓		Dug well (no MOE record) - not used in 15 years Pond on property
10	Mr. & Mrs. J.C. Ford	5 Town of Milton (formerly Trafalgar Twp.)	6	294		✓		Bored well (MOE Well 2589) - 12.2m (40 ft.) deep - water quality good, a little hard, supplies household - does not run dry Pond used for Stock watering
11	Mr. & Mrs. R.A. Davison	4 Town of Milton (formerly Trafalgar Twp.)	6	103-1	✓			Drilled well (no MOE record) - 10.7 to 12.2m (35 to 40 ft.) deep, supplies household - iron and hard, use softener and a purifier - does not run dry
12	Mr. Colin Marshall	3 Town of Milton (formerly Trafalgar Twp.)	6	1-2		✓	✓	Rented Farm - cistern which is filled with hauled water 3-4 times/year. Spring Fed Pond Dug well (no MOE record) - 7.6m (25 ft.) deep

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site PI-13N Sheet 5 of 8

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s	Cistern	Remarks
12	(continued)	1 Town of (formerly Twp.)	5 Milton Trafalgar		✓			Owned Farm - has a well water is a little hard no other information provided.
13	Mr. & Mrs. J.C. Marshall	3 Town of (formerly Twp.)	5 Milton Trafalgar	210-2	✓		✓	Drilled well (no MOE record) - 15m (50 ft.) deep with shale at 5.5m (15ft.) - does not run dry - water is not used for drinking too salty used for toilet and laundry Cistern used for bathing Bottled water for drinking
14	Mr. J.B. Marshall	3 Town of (formerly Twp.)	5 Milton Trafalgar	59-2		2		Dug wells (no MOE record) House well - dug by hand - 5.5m (18 ft.) deep - water quality hard calcium, iron - runs dry during dry years Barn well - stock - dug by hand - runs dry every Fall Pond for stock watering

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site PI-13N Sheet 6 of 8

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
15	Mr. & Mrs. A. McKee	2 Town of Milton (formerly Trafalgar Twp.)	6	411-G		✓	✓	Bored Well (MOE Well 3210) - 11.3m (37 ft.)deep, supplies house - water quality good, hard - does not run dry Cistern, supplies household
16	Mr. & Mrs. A. Endicott	2 Town of Milton (formerly Trafalgar Twp.)	6	403-G		✓		Bored well (MOE Well 2581) - 11m (36 ft.) deep - quality is good, hard - gets low does not run dry - supplies household
17	Mr. Adwin Jansen	2 Town of Milton (formerly Trafalgar Twp.)	6	270		✓	✓	Cistern -4500 (1000 gal.) - water hauled in from Milton 8 times a year Bored well (no MOE record) - dry 2 Ponds on property
18	Land Fund Limited J.W.L. Monaghan	3 Town of Milton (formerly Trafalgar Twp.)	6	56-2				No water use reported
19	Mr. & Mrs. A. Clancy	4 Town of Milton (formerly Trafalgar Twp.)	7	235-1		✓		Bored well (MOE well 2624) - 9.7m (32ft.) deep - water quality good, hard, iron,calcium does not run dry -supplies household

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site PI-13N Sheet 7 of 8

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
20	Mr. Norman Biggar and father Harold	4 & 5 2 Town of (formerly Twp.)	7 6 Milton Trafalgar	108-2				No water use reported.
21	Mr. K. Merry	5 Town of (formerly Twp.)	6 Milton Trafalgar	595				No water use reported
22	S. Stadler Farm Manager for Dr. T. Molony	4 Town of (formerly Twp.)	5 Milton Trafalgar	256-2	✓	2		Drilled well (no MOE record) - 24.4 (80ft.) deep - not used salty Dug well (no MOE record) - dry Dug well (MOE well 5287) - 8.5m (28 ft.)deep - water quality hard,iron Pond water for irrigation
23	Mr. & Mrs. M. MacKinnon	2 Town of (formerly Twp.)	5 Milton Trafalgar	590				No water use reported

Table 5 SUMMARY OF SITE INTERVIEW DATA

Site PI-13N Sheet 8 of 8

Number	Individuals Interviewed	Lot	Conc.	Interview No.	Drilled Well(s)	Dug/ Bored Well(s)	Cistern	Remarks
24	Mr. Bill Wilson Ontario Land Corporation	3 &4 Town of (formerly Trafalgar Twp.)	6 Milton	53-2				No water use reported - property leased to Mr. C. Marshall
25	Schwitan	3 Town of (formerly Trafalgar Twp.)	7 Milton		✓	✓		Morrison Beatty Ltd. Well survey Drilled well, well no. 13N-24 (no MOE record) Dug/Bored well, well no. 13N-23 (no MOE record)
26	Maher	3 Town of (formerly Trafalgar Twp.)	7 Milton		✓			Morrison Beatty Ltd. well survey Drilled well, well no. 13N-22 (no MOE record)
27	no name provided	5 Town of (formerly Trafalgar Twp.)	6 Milton			2		Morrison Beatty Ltd. well survey 2 Dug/Bored wells, no's. 13N-9, 13N-10 (no MOE records)

Interview Identification Number: _____

PHYSICAL RESOURCES - WATER

We are interested in the water used on this property: where it comes from, its quality, and how much you use.

1. What is this household's source of supply for domestic water? (e.g., drinking, laundry, toilet)

drilled water	☐	Locate on map with symbol Dr-H
dug wells	☐	Locate on map with symbol Du-H
stream water	☐	Locate on map with symbol *SW-H
cistern	☐	Locate on map with symbol *C-H
bottled water	☐	
municipal main	☐	
other, specify		_____

2. What is the water supply for the livestock and irrigation on this property?

drilled wells	☐	Locate on map with symbol Dr-A
dug wells	☐	Locate on map with symbol Du-A
streams or dams	☐	Locate on map with symbol *SW-A
cisterns	☐	
municipal main	☐	
other (e.g., ponds)		_____

3. Are there any streams or ponds on your property?

streams	Yes ☐	No ☐
ponds	Yes ☐	No ☐

4. What can you tell us about the quality of the water

a) you use or drink? (hard, soft, sulphurous, iron, salty, etc.) _____

_____

_____

_____

b) in the streams or ponds? _____

_____

_____

_____

5. Do the wells, cisterns or streams that you use for water supply ever go dry? If so, how often? _____

_____

_____

_____

Interview Identification Number: _____

6. Can you tell us anything about the construction of the wells? (e.g., when they were drilled, depth, type of pump, name of the driller) _____

7. Has any portion of your property been filled or excavated? If so, please show where on the map. (Locate on map with symbol EV.)

8. Do you know where there are any gas or oil wells on your property or the property you farm - in use or abandoned? Please show their locations on the map with the symbol GW.

9. Please tell us about any problems with flooding in the creeks and streams on your property. Please show locations of the flooded areas on the map. (Locate with symbol FA.) _____

8.3 BOREHOLE LOGS

8.3.1 GARTNER LEE ASSOCIATES LIMITED (GLAL) BOREHOLE LOGS

8.3.2 MORRISON BEATTY LIMITED BOREHOLE LOGS

8.3.1 GARTNER LEE ASSOCIATES LIMITED (GLAL) BOREHOLE LOGS

Borehole locations are shown in Figure 4 (in map pocket).

Borehole logs are based on field notes which have been verified by the project geologist following re-examination of the samples.

Continuous samples were obtained by advancing a large split tube (8.9 cm x 152 cm) through the hollow stem augers.

Standard penetration tests were performed at 1.5 m intervals and water contents were measured in samples taken from the 'nose-piece' of the standard split spoon sampler.

Textural descriptions are provided for each geologic unit and each deposit is named to indicate its origin.

All material descriptions are based on visual hand-sample examination and no laboratory grain size analyses were performed. Textural descriptions follow a Particle Size Classification System (see Glossary of Selected Terms, Section 8.6).

Borehole elevations are estimated from the 1:10 000 scale base map contours. All elevations are above sea level (ASL) and are estimated to the nearest metre.

The term pebble has been used to describe gravel-sized rock particles within a fine grained soil matrix.

GEOTECHNICAL NOTES AND ABBREVIATIONS

Standard Penetration Resistance 'N' - The number of blows required to advance a standard split spoon sampler 30 cm into the subsoil, driven by means of a 63.5 kg hammer falling freely a distance of 75 cm.

The consistency of cohesive soils and the relative density or denseness of cohesionless soils are described as follows:

Consistency	'N' Blows per 0.3 m	Denseness	'N' Blows per 0.3 m
Very soft	0-2	Very Loose	0-4
Soft	2-4	Loose	4-10
Firm	4-8	Compact	10-30
Stiff	8-15	Dense	30-50
Very Stiff	15-30	Very Dense	> 50
Hard	> 30		

ABBREVIATIONS

WTPL - Wetter than Plastic Limit

DTPL - Drier than Plastic Limit

APL - About Plastic Limit

Wp - Plastic Limit

WL - Liquid Limit

SS - Split Spoon Sample

T - Split Tube Sample

BOREHOLE NO. GL 1 (13N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** October 4, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** AB/AC

GROUND ELEVATION 190 m (approximately) **PROJECT NO.** 84-S.18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.1	TOPSOIL: very dark greyish brown silt topsoil, numerous roots								
	SILT TILL: brown to dark greyish brown silt till, heavily weathered to ±1 m, numerous shale fragments, discoloured fractures (black) common 3.1 to 3.9 m, rusty brown discolouration along diagonal fracture 4.0 to 4.6 m, moist, compact to dense (Halton Till)			1	SS	28	13		
				2	SS	33	11		
4.6				3	SS	18	11		
5.9	MEDIUM TO FINE SAND WITH SILT: grey to brown medium to fine sand, occasional pebbles, silt from 4.6 to 4.9 m, sand is rusty brown below 5.1 m, moist			4	SS	36	13		
	SILT TILL: dark grey varying to reddish brown (with depth) silt till, increasing pebble content with depth, lower contact gradational with shale bedrock, numerous reddish brown shale fragments to 10 cm, saturated, very dense. (Lower Till)			5	SS	*	9	* 56/0.15 m	
				6	SS	91	8		
9.6									
	SHALE: reddish brown shale, with occasional grey-green zones, occasional harder bed or laminae, occasional very soft zones. (Queenston Formation)								
13.3									
	Borehole terminated at 13.3 m in shale.								

Gartner Lee Associates Limited

BOREHOLE NO. GL 2 (13N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation — DATE October 3, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling — GEOLOGIST AB/AC

GROUND ELEVATION 191 m (approximately) — PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: very dark greyish brown silt topsoil, occasional roots								
	CLAYEY SILT TO SILT TILL: brown to dark grey clayey silt to silt till, sandy zones in till below ±5.0 m, heavily weathered to ±1 m, numerous fractures to 2.0 m, occasional carbonate infilled fracture to 4.6 m, four fractures with rusty discolouration 4.3 to 4.9 m, very stiff to hard (Halton Till)			1	SS	26	13		
				2	SS	40	10		
				3	SS	19	12		
				4	SS	18	10		
7.0									
	SANDY SILT TILL: brown sandy silt till, variable, massive to laminated, with sandy zones, sand laminae and beds to 10 cm, medium sand 10.6 to 10.7 m, sandy zone in till 10.7 to 11.3 m silty fine to medium sand 11.3 to 11.4 m, fine to medium sand 11.7 to 12.1 m, silty sandy gravel 13.3 to 13.5 m, saturated, very dense (Lower Till)			5	SS	24	7		
				6	SS	*	5	* 73/0.25 m	
				7	SS	*	11	* 80/0.2 m	
				8	SS	80	8		
13.9									
	SILTY SANDY GRAVEL: reddish brown to grey silty sandy gravel, very poorly sorted, abundant reddish brown shale, grades into underlying shale bedrock, saturated, very dense.			9	SS	93	10		
				10	SS	100	7		
16.7									
	SHALE: reddish brown shale to siltstone, occasional grey-green zones, occasional hard bands, weathered (Queenston Formation)			11	SS	*	8	* 110/0.23 m	
18.1									
	Borehole terminated at 18.1 m in shale.								

Gartner Lee Associates Limited

BOREHOLE NO. GL 3 (13N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** October 3, 1984

BOREHOLE TYPE 108 m ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** E.K./AC

GROUND ELEVATION 191 m (approximately) **PROJECT NO.** 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: very dark greyish brown silt topsoil with roots and vegetation.								
	SILT TILL: brown silt till with clay, heavily weathered to ±1 m, grey carbonate and black stained fractures to 2.5 m, hard (Halton Till)			1	SS	38	12		
3.1				2	SS	92	9		
	SILTY SAND TO SANDY SILT TILL: dark greyish brown silty sand to sandy silt till, variable, massive and very sandy to ±7 m, occasional sand bed to 5 cm, occasional cobble (to 8 cm), massive to laminated, rusty brown stained fractures 4.1 to 4.7 m, moist to ±4 m, saturated below 4 m, very dense (Lower Till)			3	SS	*	N/A	* 40/0.15 m	
				4	SS	*	10	* 97/0.15 m	
				5	SS	*	11	* 40/0.15 m	
				6	SS	*	14	* 89/0.15 m	
				7	SS	99	10		
				8	N/A	N/A	N/A	no sample	
				9	SS	*	7	* 62/0.15 m	
13.2									
	GRAVEL, SAND AND SILT: dark grey layers of sandy gravel, sand and silt, with inclusions of silt till, variable, saturated, very dense.			10	SS	*	9	* 60/0.15 m	
				11	SS	*	16	* 70/0.15 m	
16.3									
	SHALE: reddish brown shale to siltstone, with hard bands, heavily fractured, grey-green banding and pockets (Queenston Formation)								
19.7									
	Borehole Terminated at 19.7 m in shale								

Gartner Lee Associates Limited

BOREHOLE NO. GL 4 (13N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation — DATE October 2, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling — GEOLOGIST EK/AC

GROUND ELEVATION 192 m (approximately) — PROJECT NO. 84-S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: black silt topsoil, with roots and organics								
	SILT TO CLAYEY SILT TILL: brown silt to clayey silt till, heavily weathered to ±1 m, numerous carbonate infilled fractures to ±2 m, numerous reddish brown and grey-green shale fragments, 1 cm thick rusty coloured fine sand lamina at 4.9 m, rusty coloured fracture at 5.6 m, DTPL to ±4.0 m, APL 4.0 m to 7.1 m, very stiff to hard (Halton Till)			1	SS	44	12		
				2	SS	79	10		
				3	SS	43	11		
				4	SS	15	19		
7.1				5	SS	N/A	9	No "N" Value	
	SILT TO SANDY TILL: brown silt to sandy till, variable, massive to laminated, with inclusions and laminae of silt and fine sand to 20 cm, fracture with slight rusty stain at 9.0 m, gradational lower boundary, saturated, very dense (Lower Till)			6	SS	*	8	* 60/0.15 m	
				7	SS	*	11	* 55/0.15 m	
12.8				8	SS	*	13	* 50/0.15 m	
	SILTY SANDY FINE GRAVEL: grey (top) to reddish brown (bottom) silty sandy fine gravel (to 1 cm), occasional pebbles to 6 cm, very dense, saturated			7	SS	*	7	* 60/0.15 m	
14.0									
	SILT TO CLAYEY SILT: grey silt to clayey silt, laminated, occasional silty fine sand laminae to 0.5 cm, hard			10	SS	*	11	* 60/0.15 m	
16.3									
17.1	CLAYEY SILTY SANDY FINE GRAVEL: reddish brown clayey silty sandy fine gravel (to 2 cm), increasing content and size with depth			11	SS	*	13	* 60/0.15 m	
	SHALE TO SILTSTONE: reddish brown shale to siltstone, occasional grey-green zones, thinly bedded, harder calcareous zones, upper 0.5 m heavily weathered (Queenston Formation)								
20.9									
	Borehole Terminated at 20.9 m in shale								

Gartner Lee Associates Limited

BOREHOLE NO. GL 5 (13N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation **DATE** October 1, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continuous Sampling **GEOLOGIST** EK/AC

GROUND ELEVATION 185 m (approximately) **PROJECT NO.** 84 S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: brown silt topsoil, occasional roots and vegetation								
	SILT TO CLAYEY SILT TILL: brown to dark yellowish brown silt to clayey silt till, heavily weathered to ±1 m, fractures common to ±2.4 m, numerous reddish brown and grey-green shale pebbles, hard (Halton Till)			1	SS	61	11		
				2	SS	*	17	* 60/0.15 m	
4.1									
	SANDY SILT TO SILTY SAND TILL: dark greyish brown to reddish brown (with depth) sandy silt to silty sand till, numerous shale pebbles (increasing with depth) sand inclusions and interbeds to 1.5 cm, rusty fracture 4.1 to 4.6 m, saturated, very dense (Lower Till)			3	SS	*	13	* 55/0.15 m	
6.1				4	SS	*	11	* 85/0.15 m	
				5	SS	*	N/A	* 50/0.15 m	no sample
	SHALE: reddish brown shale to siltstone, occasional grey-green zones, occasional calcareous zones, thinly bedded, several soft zones in core (Queenston Formation)								
10.2	Borehole Terminated at 10.2 m in shale								

Gartner Lee Associates Limited

BOREHOLE NO. GL 6 (13N)

PROJECT NAME Phase 4A Drilling and Sampling

CLIENT Ontario Waste Management Corporation — DATE October 1, 1984

BOREHOLE TYPE 108 mm ID Hollow Stem Auger, Continous Sampling — GEOLOGIST AB/AC

GROUND ELEVATION 189 m (approximately) — PROJECT NO. 84.S18.3

DEPTH (m)	STRATIGRAPHIC DESCRIPTION	STRATIGRAPHY	MONITOR DETAILS AND NUMBER	SAMPLE NO.	SAMPLE TYPE	SAMPLE 'N' VALUE	SAMPLE % WATER	PENETRATION RESISTANCE BLOWS/0.3m (20 40 60)	WATER CONTENT % / COMMENTS (10 20 30; Wp — Wl)
0.2	TOPSOIL: brown clayey silt topsoil, occasional roots								
	SILT TO CLAYEY SILT TILL: brown silt to clayey silt till, heavily weathered with grey carbonate infilled fractures to ±1.5 m, numerous shale fragments, fractures with black discolouration to 2.8 m, lower contact gradational over ±10 cm, hard (Halton Till)			1	SS	36	12		
				2	SS	*	12	* 60/0.05 m	
4.7				3	SS	51	11		
	SANDY SILT TO SILT TILL: brown to dark greyish brown sandy silt to silt till, variable, with inclusions of silt and fine to medium sand, massive to indistinctly laminated, rusty brown discoloured fine sand laminae (to 1 cm) at 8.2 to 8.4 m, three very fine sand beds (to 10 cm) 9.2 to 9.8 m, fine sand 10.7 to 10.9 m, medium to fine sand 11.9 to 12.0 m, Moist to wet to ±7 m, saturated beneath ±7 m, very dense (Lower Till)			4	SS	*	10	* 50/0.08 m	
				5	SS	*	6	* 50/0.08 m	
				6	SS	68	11		
				7	SS	91	8		
12.7				8	SS	34	9		
	FINE TO MEDIUM SAND: grey to reddish brown fine to medium sand, becoming gravelly with depth, abundance of shale fragments and red colour in lower ±1 m, increasing silt with depth, very dense, saturated			9	SS	50	12		
				10	SS	74	20		
16.8				11	SS	*	9	* 75/0.15 m	
	SILTSTONE TO SHALE: reddish brown siltstone to shale, occasional grey-green zone, calcareous throughout with harder zones, occasional soft weathered zones (Queenston Formation)								
20.1	Borehole terminated at 20.1 m in shale								

8.3.2 MORRISON BEATTY LIMITED BOREHOLE LOGS

Four boreholes were completed on and in the vicinity of Site PI-13N by Morrison Beatty Limited for the Town of Milton. The locations of these boreholes are presented in Figure 4 (in map pocket).

Continuous samples were obtained by advancing a large split tube (8.9 cm x 152 cm) through the hollow stem augers.

Ground elevations at the boreholes are estimated from the contours on the 1:10 000 scale base maps and are rounded to the nearest metre in Figure 4.

morrison beatty limited
consulting engineers and hydrogeologists
4500 dixie road, unit 12a, mississauga, ontario L4W 1V7 (416-624-9308)

October 2, 1984

Mr. Ken Goff
Gartner Lee Associates Limited
Toronto-Buttonville Airport
Markham, Ontario
L3P 3J9

Dear Sir:

re: Hydrogeologic Studies of
Milton Sites for
OWMC

We have been authorized by the Town of Milton to meet with you to review the results of our preliminary hydrogeologic studies at the three Milton sites. This letter confirms our meeting at 11:30 AM today to discuss our work at the Omagh site (OWMC Site No. P.I.-13N).

We have enclosed preliminary copies of the borehole logs at the four locations we tested on this site. A map showing the test locations and private well locations is also included.

The well logs are abbreviated, since detailed examination of the borehole samples has not been completed. They show the significant stratigraphic units only. Two of the four boreholes at the Omagh site identified four metres or more of stratified drift below the surficial till.

Yours very truly,
MORRISON BEATTY LIMITED

Brian W. Beatty, P.Eng.

BWB/lf

morrison beatty limited
consulting engineers and hydrogeologists

13N-OW1

CLIENT _____ FILE NO. 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site13N)

GEOLOGIST / ENGINEER TH DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL	3	10	
	6	20	
	9	30	
SHALE	12	40	
	15	50	
	18	60	
	21	70	
	24	80	
	27	90	
	30	100	
	33	110	
	36	120	
	39	130	
	40		

PRELIMINARY

morrison beatty limited
consulting engineers and hydrogeologists

13N-OW2

CLIENT _____ FILE NO. 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site 13N)

GEOLOGIST / ENGINEER TH DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL	3	10	
	6	20	
	9	30	
SHALE	12	40	
	15	50	
	18	60	
	21	70	
	24	80	
	27	90	
	30	100	
	33	110	
	36	120	
	39	130	
	40		

PRELIMINARY

morrison beatty limited
consulting engineers and hydrogeologists

13N-OW3

CLIENT _____ FILE NO. 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site 13N)

GEOLOGIST / ENGINEER TH DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL	3	10	
	6	20	
	9	30	
STRATIFIED DRIFT	12	40	
TILL			
STRATIFIED DRIFT	15	50	
TILL			
SHALE	18	60	
	21	70	
	24	80	
	27	90	
	30	100	
	33	110	
	36	120	
	39	130	
	40		

PRELIMINARY

morrison beatty limited
consulting engineers and hydrogeologists

13N-0W4

CLIENT _____ FILE NO. 413-841

PROJECT Hydrogeologic Study LOCATION Proposed OWMC Sites (Site 13N)

GEOLOGIST / ENGINEER TH DATE COMPLETED July/84

DESCRIPTION	DEPTH metres	DEPTH feet	WELL DETAIL
TILL	3	10	
	6	20	
	9	30	
STRATIFIED DRIFT	12	40	
	15	50	
SHALE	18	60	
	21	70	
	24	80	
	27	90	
	30	100	
	33	110	
	36	120	
	39	130	
	40		

PRELIMINARY

8.4 FIELD STATION DESCRIPTIONS

Field stations consisting of hand auger holes are located in Figure 4. A standard 380 mm soils auger was used to examine soil profiles. No samples were taken at field stations.

FIELD STATION LOGS, SITE PI-13N

Field Station #1

0.0-0.5 m	brown to reddish brown clayey silt till containing red shale particles

Field Station #2

0.0-0.2 m	topsoil
0.2-1.1 m	brown clayey silt till with reddish brown staining containing red shale fragments - dry to 0.3 m, damp to 1.1 m

Field Station #3

0.0-0.2 M	black topsoil
0.2-0.9 m	dark brown clayey silt till, damp

Field Station #4

0.0-0.2 m	dark reddish brown topsoil
0.2-0.9 m	medium to dark brown clayey silt to silty clay till, few pebbles, damp to slightly moist

Field Station #5

0.0-0.2 m	black topsoil
0.2-0.9 m	dark to medium brown clayey silt to silty clay till, few pebbles, moist - dense below 0.6 m

Field Station #6

0.0-0.8 m	grey brown clayey silt to silty clay till with occasional pebble - dry

Field Station #7A

0.0-0.9 m	grey brown clayey silt till with occasional pebble

Field Station #7B

0.0-1.1 m	grey brown clayey silt till with occasional pebble shale fragments make up about 1-2% of sample

8.5 SUPPORTING CALCULATIONS AND METHODS

In 1856, the French hydraulics engineer Henry Darcy reported that flow through a porous medium is proportional to the head loss and inversely proportional to the distance travelled. The formulation of these relationships is called Darcy's Law and may be written as specific discharge (v) = hydraulic conductivity (K) x gradient (i). The specific discharge is the total discharge per unit area of the discharging porous medium and does not indicate the velocity of the water 'particles'. The velocity of the water (average linear velocity, $\bar{v}$) may be obtained by dividing the specific discharge (v) by the effective porosity (n) of the porous medium. Because effective porosity is always less than 1, the average linear velocity ($\bar{v}$) is always greater than the specific discharge (v).

$$\text{Average Linear Velocity } (\bar{v}) = \frac{\text{hydraulic conductivity } (K) \times \text{gradient } (i)}{\text{effective porosity } (n)}$$

Once the above parameters are known for a porous medium, an average linear velocity may be calculated. The following example utilizes values typical of lateral flow in the fractured zone:

Lateral Ground Water Flow

- hydraulic conductivity (k) 1×10^{-7} m/s
- lateral gradient (i) 0.01
- effective fracture porosity (n) 0.0001

$$\bar{v} = \frac{Ki}{n} = \frac{1 \times 10^{-7} \times 0.01}{0.0001} = 1.0 \times 10^{-5} \text{ m/s or } \approx 300 \text{ m/year}$$

Vertical Ground Water Flow

The application of Darcy's Law to ground water flow through layered porous media when the layers have differing thicknesses and hydraulic properties is discussed in Freeze and Cherry (1979) and is summarized below with regard to the area under study. The layered porous media of interest here are the confining layer subunits which include the fractured and the unfractured zones of the Halton Till. Estimating the rates of ground water flow in each of these layers involves (1) the calculation of a single equivalent hydraulic conductivity for the two layers, (2) calculation of the specific discharge through the layers and (3) the calculation of average linear velocities in each of the layers.

The calculation of an equivalent hydraulic conductivity (Ke) for the two-layer situation is:

$$Ke = \frac{d(FCL + CL)}{\frac{dFCL}{KFCL} + \frac{dCL}{KCL}}$$

where K and d are the hydraulic conductivity and thickness respectively and the subscripts are 'e' (equivalent), 'FCL' (fractured confining layer), and 'CL' (confining layer).

The calculation of specific discharge (v) uses the equivalent hydraulic conductivity (Ke) and the overall vertical gradient (i) across the layers in Darcy's Law:

$$v = Ki$$

And finally, the average linear ground water velocity ($\bar{v}$) in each layer is obtained by dividing the specific discharge (v) by the effective porosity (n) for each of the layers involved.

The following example uses numbers similar to those in the report (values relate to the layers identified above; thicknesses are in m and hydraulic conductivities are in m/s).

$$Ke = \frac{7.0}{\frac{5.0}{1x10^{-7}} + \frac{2.0}{1x10^{-9}}} = \frac{7.0}{2.0x10^{9}} = 3.4x10^{-9} \text{ m/s}$$

where the vertical gradient (i) is 0.5

$$v = Ke(i) = 3.4x10^{-9} \times 0.5 = 1.7x10^{-9} \text{ m/s}$$

The average linear velocity ($\bar{v}$) = specific discharge ÷ effective porosity for each individual layer.

For the fractured confining layer, porosity (n) = 0.0001 and the average vertical linear velocity ($\bar{v}$) =

$1.7x10^{-9}/0.0001 = 1.7x10^{-5}$ m/s or $\approx$500 m/year.

For the unfractured confining layer, no effective porosity value is available and consequently a total porosity value of 0.3 is used to calculate an average linear velocity ($\bar{v}$) =

$1.7x10^{-9}/0.3 = 5.7x10^{-9}$ m/s
or $\approx$0.18 m/year.

(These are approximate values and are usually rounded to one significant figure in the text).

The major assumptions for their calculations are:

(1) Flow is steady state,
(2) flow is in a direction perpendicular to the layering,
(3) layers are homogeneous and isotropic,
(4) flow is governed by Darcy's Law. A more complete and theoretical discussion is given in Freeze and Cherry (1979).

For a more detailed discussion of ground water flow rates through the confining layer based on advection and diffusion calculations, the reader is referred to Appendix A of the report entitled "Site Selection Process, Phase 4A; Selection of Preferred Site(s), Geologic, Hydrogeologic, and Geotechnical Considerations" (GLAL 1985).

8.6 GLOSSARY OF SELECTED TERMS

Sources are provided at the rear of this section and are referenced by the bracketed number following each definition.

Some definitions are altered slightly to reflect useage in this report and may not reflect the wide range of meanings provided in the source.

8.6 GLOSSARY OF SELECTED TERMS

Alluvium
Sediment composed of organic material, clay, silt, sand, gravel cobbles, or boulders deposited by postglacial streams. (2)

Aquifer
A body of sediment (or rock) that contains sufficient saturated permeable material to conduct ground water and yield economically significant quantities of ground water to wells and springs.(2)

Bearing Pressure (Allowable)
Means the maximum pressure that may be safely applied to a soil or rock by the foundation unit in design under expected loading and subsurface conditions. (8)

Confining Bed (Layer)
A body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers. (1)

Darcy's Law
For the velocity of percolation of water in saturated soil: Velocity = coefficient of permeability x hydraulic gradient. (4) (hydraulic conductivity is used in place of coefficient of permeability in this report).

Desiccated Crust
The exposure of fine-grained sediments to drying is accompanied by shrinkage and possibly cracking. Precompression of the upper portions of clay layers by drying is frequently observed in many of the profiles encountered in practice. The effects of desiccation are an increase in strength and a decreased water content. (6)

Drawdown
The lowering of the water level in a well as a result of withdrawal. (1)

Drift
A general term applied to all rock material (clay, silt, sand, gravel, boulders) transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier. (1)

Evaporite
A nonclastic sedimentary rock composed primarily of minerals produced from a saline solution as a result of extensive or total evaporation of the solvent. Examples include: gypsum, anhydrite, rock salt, primary dolomite, and various nitrates and borates. (3)

Geometric Mean
The nth root of the product of the values of n positive numbers; the antilogarithm of the mean of the logarithms of individual values. (1)

Geotechnical, Geotechnics
Pertaining to the broad field of geotechnics. The application of scientific methods and engineering principles to the acquisition, interpretation, and use of knowledge of materials of the earth's crust for the solution of engineering problems. (1)

Glacial Lake
A lake fed predominantly by glacial meltwater or a lake in a depression in part closed by glacial ice. Includes lakes not directly adjacent to the glacier and lakes lying against or on a glacier, and fed mainly by waters derived from the melting of a glacier. (2)

Glaciofluvial
Pertaining to streams flowing from glaciers or to the deposits made by the streams. (2)

Glaciolacustrine
Pertaining to or characterized by glacial and lacustrine (lake) conditions. Material deposited in lakes affected by glacier ice, or deposited by meltwater flowing directly from glaciers into a lake. (2)

Ground Water
Subsurface water occurring below the water table (phreatic surface) in the saturated zone in which all pores are filled with water under hydrostatic pressure. This contrasts with subsurface water above the water table, which is referred to as soil moisture. (2)

Grout
A cement slurry of high water content, fluid enough to be poured or injected into spaces and thereby fill or seal them. (1)

Hardness (Water)
A property of water causing formation of an insoluble residue when the water is used with soap, and forming a scale in vessels in which water has been allowed to evaporate. It is primarily due to the presence of ions of calcium and magnesium, but also to ions of other alkali metals, other metals (e.g. iron), and even hydrogen. Hardness of water is generally expressed as parts per million as $CaCO_3$ (40 ppm Ca produces a hardness of 100 ppm as $CaCO_3$); also as milligrams per litre, and is the combination of carbonate hardness and noncarbonate hardness. (1)

Hazardous Waste
Waste that poses a present or potential danger to human beings or other organisms because it is toxic, flammable, radioactive, explosive, or has some other property that produces substantial risk to life. (1) (Use here excludes radioactive waste)

Heave
A predominantly upward movement of a surface, caused by expansion or displacement, as from swelling clay, removal of overburden, seepage pressure, or frost action. (1)

Hydraulic Gradient
In an aquifer, the rate of change of total head per unit of distance of flow at a given point and in a given direction. (1)

Hydraulic Head
The height of the free surface of a body of water above a given subsurface point. (1)

Hydraulic conductivity
The proportionality factor in Darcy's law as applied to the viscous flow of water in soil, that is, the flux of water per unit gradient of hydraulic potential. (3)

Hydrogeology
The science that deals with subsurface waters and with related geologic aspects of surface waters. (1)

Hydrostratigraphic Unit
A term proposed by Maxey (1964, p. 126) for a body of rock having considerable lateral extent and composing "a geologic framework for a reasonably distinct hydrologic system". (1) (used here for soil and rock).

Infiltration
The flow of a fluid into a solid substance through pores or small openings; specifically the movement of water into soil or porous rock. (1)

Lamina
The thinnest recognizable unit layer of original deposition in a sediment or sedimentary rock, differing from other layers in colour, composition, or particle size; specifically such a sedimentary layer less than 1 cm in thickness (commonly 0.05-1.00 mm thick). (1)

Log
A continuous record as a function of depth, usually graphic and plotted to scale on a narrow paper strip, of observations made on the rocks and fluids of the geologic section exposed in a well bore. (1) (used here for soil and rock).

Moraine
Accumulation of glacial material (mainly till) deposited by glaciers. (2)

Particle Size Classification System (9)

Name	Qualifying Term	Approximate Particle Size (mm)
Boulders		>200
Cobbles		60-200
Gravel	(Pebble)	2-60
Sand	Coarse	0.6-2
	Medium	0.2-0.6
	Fine	0.06-0.2
Silt		0.002-0.06
Clay		<0.002

Permeability
The capacity of a porous medium to transmit a liquid or gas subjected to an energy gradient (in the case of water, hydraulic gradient). (2)

Porosity
The ratio of the volume of voids to the total volume of a soil sample. (4). Effective porosity is the amount of interconnected space available for fluid transmission (3).

Quaternary
The youngest period of the two geologic time divisions of the Cenozoic Era. The Quaternary is subdivided into the Pleistocene and Recent (or Holocene) Epochs. It comprises all geologic time and deposits from the end of the Tertiary (approximately 2 million years ago) until and including the present. (2)

Saturated
Said of the condition in which the interstices of a material are filled with a liquid, usually water. It applies whether the liquid is under greater than or less than atmospheric pressure, so long as all connected interstices are full. (1)

Settlement
Downward movement of a structure such as a railway bridge, dam, or building, due to compression or movement of the soil below it. (4)

Shear Strength
The internal resistance offered to shear stress. It is measured by the maximum shear stress, based on original area of cross-section, that can be sustained without failure. (5)

Two extreme conditions may be recognized: drained conditions, under which the changes in stress are applied so slowly with respect to the ability of the soil to drain that no excess pore pressures develop, and undrained conditions, under which the stresses are changed so rapidly with respect to the ability of the soil to drain that no dissipation of pore pressure takes place. (7)

Slug Test
A method of determining in situ hydraulic conductivity in a single piezometer by causing an instantaneous change in the water level by adding or displacing a known volume of water. (10)

Split Spoon Sampler
Sampling spoons for exploratory borings commonly consist of a pipe with an inside diameter of about 35 mm and an outside diameter of about 51 mm. The pipe is split lengthwise. Consequently the sampler is called a split spoon. While the sample is being taken, the two halves of the spoon are held togther at the ends by short pieces of threaded pipe. One piece serves to couple the spoon to the wash pipe. The other, which has been sharpened, serves as the cutting edge while the spoon is driven into the soil. Exact dimensions are designated in ASTM DI586-67. (7)

Static (Water) Level
That water level of a well that is not being affected by withdrawal of ground water. (1)

Stratigraphic Unit
A stratum or body of adjacent strata recognized as a unit in the classification of a rock sequence with respect to any of the many characters, properties, or attributes that rocks may possess. (1)

Surcharge Load
A weight per unit of area of fill great enough to consolidate the soil sufficiently to increase its strength or reduce its compressibility to the required extent within the time available. Compressible soils such as clays, loose silts, and most organic soils may be compacted by surcharging. (7)

Till
An unsorted mixture of clay, silt, sand, pebbles, cobbles and boulders deposited directly by glacier ice. (2)

Water Table
A surface in the saturated zone below ground level along which the hydrostatic pressure is in equilibrium with the atmospheric pressure. (2)

Weathering
The destructive process or group of processes by which earthy and rocky materials on exposure to atmospheric agents at or near the earth's surface are changed in colour, texture, composition, firmness, or form with little or no transport of the loosened or altered material; specifically, the physical desintegration and chemical decomposition of rock that produce an in situ mantle of waste and prepare sediments for transportion. (1)

SOURCES

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8.7 DETAILED FIELD METHODS

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8.7.1. INTRODUCTION

Field data for of the Phase 4A hydrogeologic onsite investigations were collected in a standardized fashion and formed part of the basis for geologic, hydrogeologic, and geotechnical comparisons of the eight candidate sites. An outline of the major field activities is shown in Figure 9. The study approach was modified only slightly on a site-by-site basis to accommodate differing circumstances and site conditions. Standard procedures for the drilling and sampling operations, as outlined in the Gartner Lee Associates Ltd. "Drilling and Sampling Protocol" document (GLAL 1984a), were adhered to throughout the drilling program. This protocol document provides examples of field forms used to document field activities and should be referred to for more detailed drilling and sampling procedural descriptions.

8.7.2. DRILL SITE IDENTIFICATION

8.7.2.1 Preliminary data analysis

A preliminary review of existing water well and test hole data was completed to establish a basis for the selection of tentative drill locations. Criteria used included the following:

- the distribution of existing test holes and water wells;
- the continuity of existing data; and
- anomalous or unusual site conditions.

While locations were selected primarily on technical grounds, practical considerations such as site access, potential crop damage, and landownership were also taken into account.

DETAILED FIELD METHODS

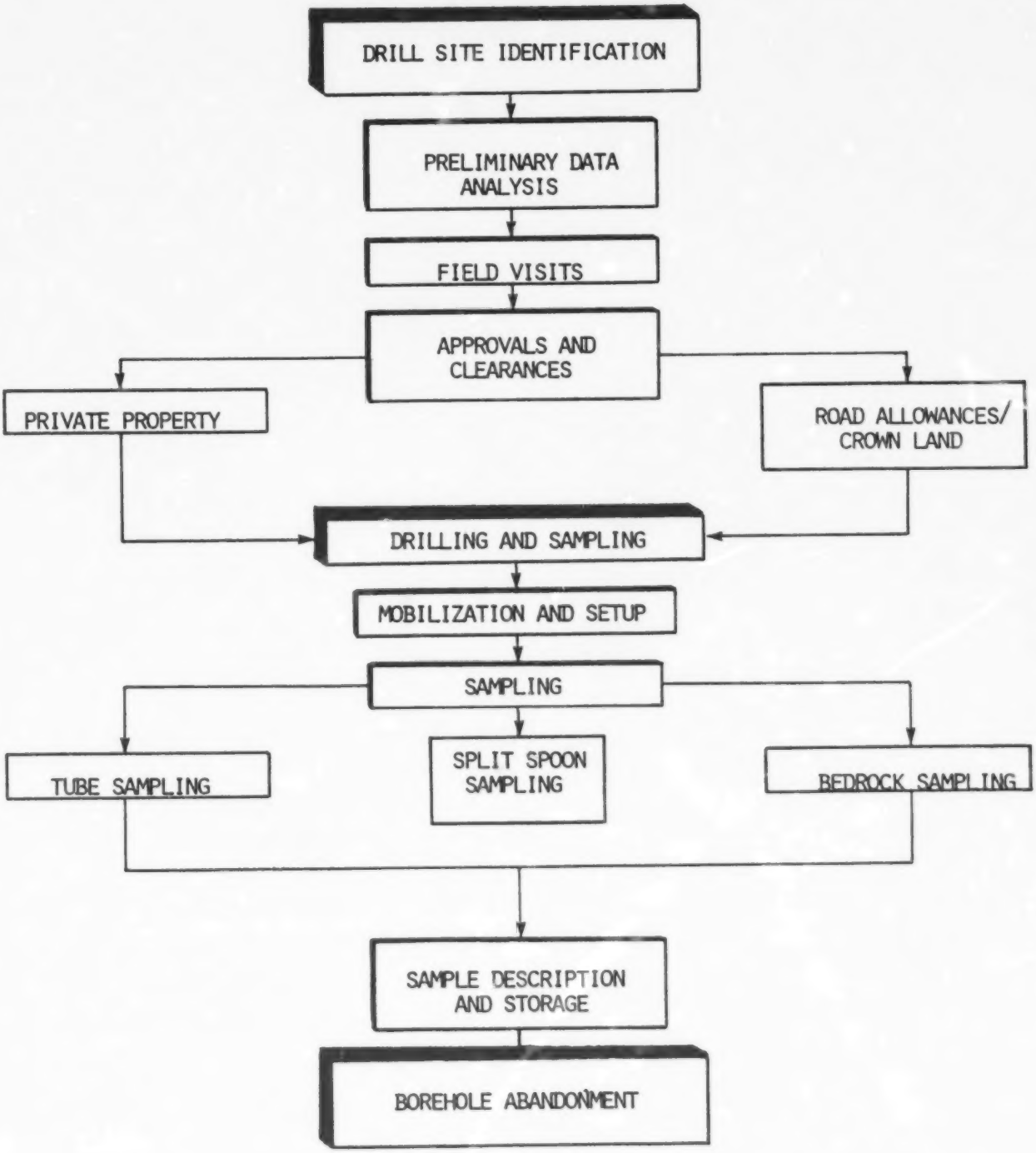

Figure 9

8.7.2.2 Field visits

The concerns of local public interest groups and individuals were also considered in selecting drill locations. Local interest groups were invited to participate during field checking of the drill locations. During these field visits, additional data on water use, local soil conditions, and wells were obtained from local residents. This information was used as a check on some of the field data obtained previously by Ecolgistics Limited during the 1984 "Walk and Talk" survey. The amount of information thus obtained varied from site-to-site and depended largely upon the degree of co-operation given by residents and landowners.

A limited amount of soil probing was completed at Candidate Sites LF-3C, LF-9C, and PI-13N using a 25 mm (1 inch) magnesium hand auger. These investigations were generally limited to a depth of 1 to 2 m. Hand augering was directed toward areas of suspected granular soils or anomalous soil conditions identified by local residents. Soil probing was confined to areas where property access was permitted. Soil descriptions are included under "Field Station Descriptions" in the individual technical site reports.

The tentative drill locations were adjusted during the field visits to avoid difficult or unsafe drilling locations. Each location was marked with a temporary wooden stake. Final adjustments were subsequently made, where necessary, to provide the required safe setbacks from buried and overhead services.

8.7.2.3 Approvals and Clearances

Clearances for both road allowances and adjacent private

or public property were pursued where identified drilling locations were located in the vicinity of local roads. Road allowances were drilled where access to private property was denied.

Landowners and tenants of affected properties were initially contacted by GLAL and verbal approval for test drilling was obtained. Approval was confirmed with a follow up letter from OWMC. For road allowance clearances, the appropriate agencies were contacted and the necessary permit approvals were obtained.

Utilities were contacted and buried service cables and/or pipes were field located by utility personnel and final adjustments of drill locations were completed. Drilling approvals and clearances were completed on a site-by-site basis.

8.7.3 DRILLING AND SAMPLING

8.7.3.1 Drilling equipment and setup

All Terrain Drilling Limited was retained to provide drilling services. The drilling equipment included truck and track mounted CME 75 auger drilling rigs. Two rigs were used simultaneously for most of the drilling program. Each rig was equipped to drill and sample both soils and bedrock. Each rig was staffed with a three man drilling crew and supervised by a GLAL geologist. The drilling program was initiated on August 13, 1984 at Site LF-3C and was completed on November 22, 1984 at Site LF-4N.

The drill rigs were set up in accordance with standard drilling practices and in a manner that allowed the safe

and efficient operation of the equipment. A safety corridor was roped-off around the drill rig to limit access to the rigs. Access to the roped-off area was restricted to individuals with proper safety equipment which included steel-toed boots and a hard hat. A record was kept of all visitors to the drill site as well as persons entering the roped-off area.

Sample documentation and storage facilities were set up at the edge of the roped-off area by GLAL. Soil and rock samples were accessible to the general public for viewing and/or photographing as the samples were being logged by the onsite geologists. Samples were subsequently sealed in tubes or core boxes, labelled, and placed in storage. On several occasions, soil sample tubes were re-opened for examination at the request of local residents.

8.7.3.2 Soil sampling

The drilling program was designed to obtain a continuous column of soil from the ground surface to and including the upper few metres of the underlying bedrock. Soil samples were obtained using hollow stem auger drilling techniques. Hollow stem augers (108 mm (4.25 inch) inside diameter) were used throughout the drilling program.

Split tube sampling. Tube samples measuring approximately 89 mm (3.5 inches) in diameter by 1.52 m (5 ft.) in length were taken continuously from ground level to the bedrock surface. The tube sampler consisted of a split tube with a bevelled sampler tip. The split tube was threaded at both ends and fastened to the drill rods as shown in Figure 10. The sampler as advanced inside the hollow stem augers with

Continuous Soil Sampling With Split Tube Sampler

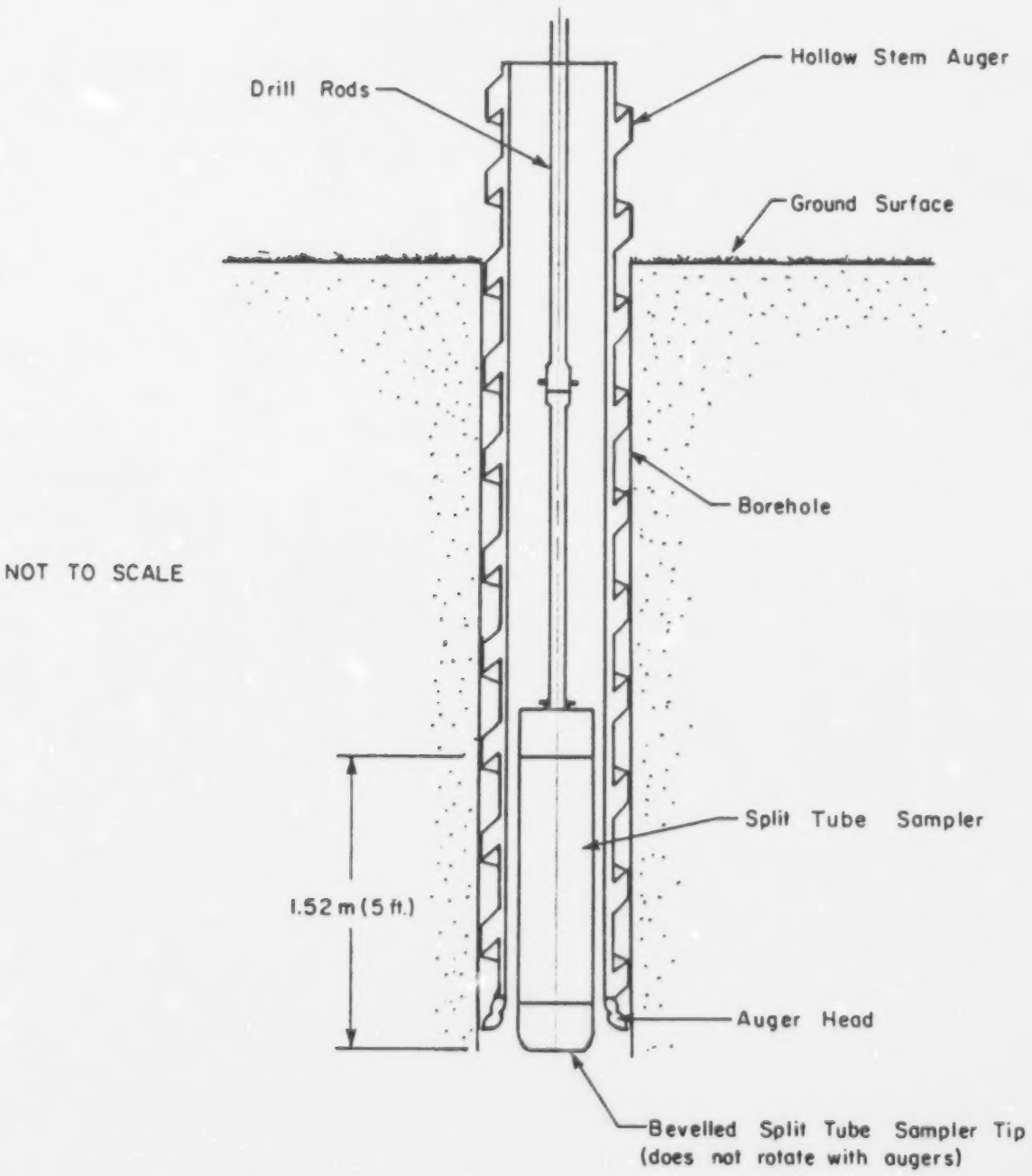

Figure 10

the bevelled tip slightly ahead of the cutting edge of the augers. A split tube sample was obtained by advancing the sampler with the rotating augers. The augers and sampler were advanced at about 1.52 m (5 ft.) intervals or until refusal, and the sampler was then withdrawn from the borehole. The soil sample was removed from the tube and the sampler washed with clean water. Sample recovery for the tube samples was generally between 90 to 100% and was recorded in the field log. Difficult drilling conditions or large cobbles occasionally resulted in lower sample recovery.

Split spoon sampling. Standard split spoon samples were taken at about 1.52 m (5 ft.) intervals throughout the soil sequence overlying bedrock and beginning at about 1.52 m 5 ft.) from the ground surface. Sample intervals are shown schematically in Figure 11.

The split spoon sampler was driven by dropping a 63.5 kg (140 lb.) weight a distance of about 750 mm (30 inches). The sampler was inserted inside the hollow stem augers in a similar fashion to the tube sampler. It was then driven into the soil below the bottom of the augers a distance of about 460 mm (18 inches) or until refusal. The number of blows required to advance the sample for each interval of about 150 mm (6 inches) was recorded in the field log. The split spoon was usually withdrawn when 50 or more blows were required to advance the sampler approximately 150 mm (6 inches) into the subsoil.

Standard split spoon samples were obtained in place of tube samples where difficult drilling conditions were

Soil & Rock Sample Intervals, Phase 4A Drilling Program

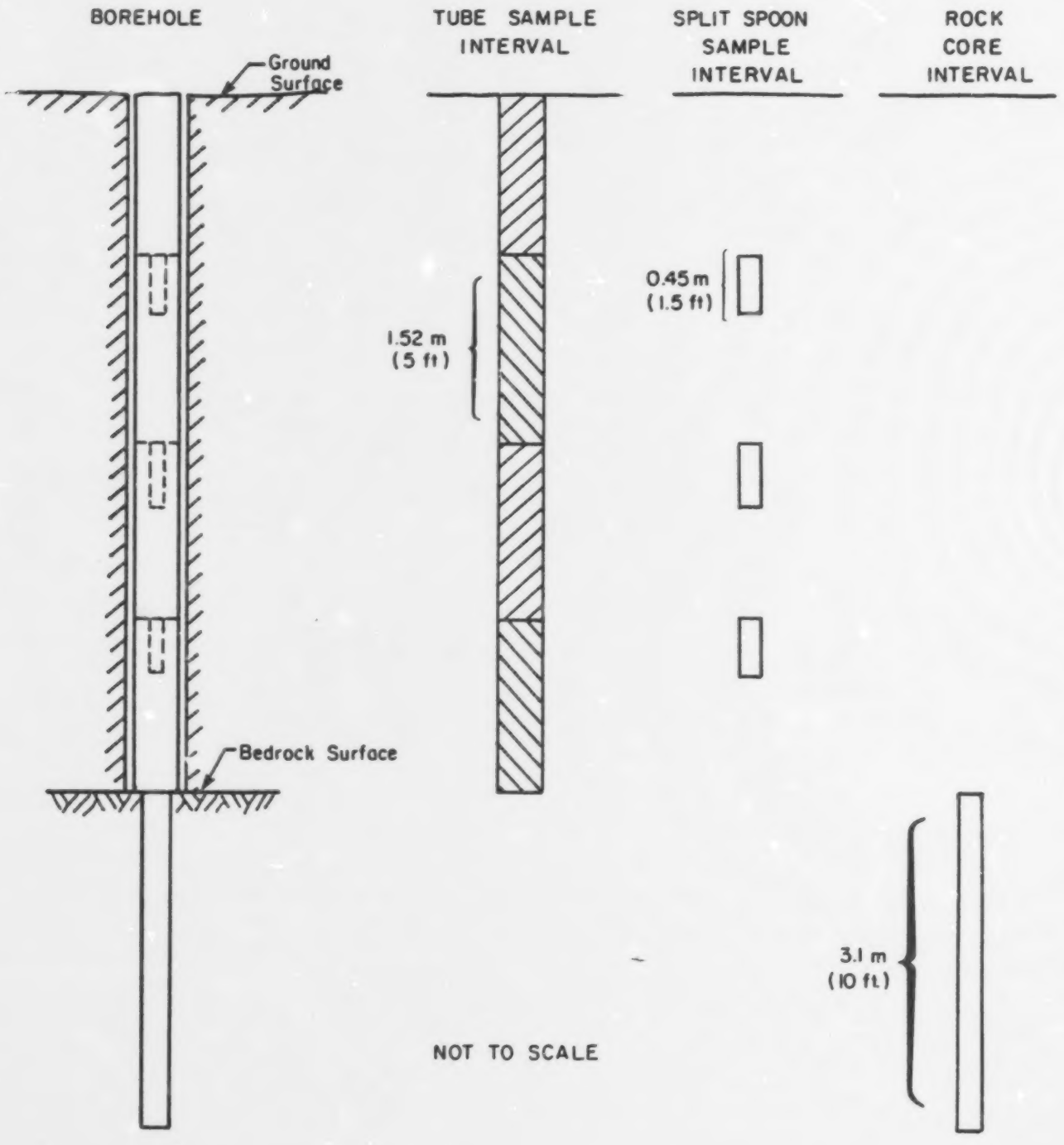

Figure 11

encountered. At Site LF-4N, Borehole 4, granular soils were encountered at a depth of about 30 m (100 ft.) causing refusal of the tube sampler. Standard split spoon samples were taken from a depth of 30 m (100 ft.) at intervals of 0.5 to 3 m (1.6 to 9.8 ft.) to a depth of about 40 m (130 ft.). Difficult soil conditions were also encountered at Site LF-2N, Borehole 1. Numerous rock fragments were encountered below a depth of about 12 m (40 ft.) at this location. Split spoon samples at 0.76 m (2.5 ft.) intervals were taken between depths of about 12 m (40 ft.) to 34 m (110 ft.).

Difficult (sandy and gravelly) soil conditions at Site PI-27E, Borehole 3 prevented tube sampling between depths of about 16 to 30 m (50 to 100 ft.). Similar fine, sandy soils were also encountered in Borehole 4 at this site at depths between approximately 24 to 30 m (80 to 100 ft.). Standard split spoon samples at 1.5 m (5 ft.) intervals were collected over these intervals at these two borehole locations.

Moisture tin samples. A small soil sample of approximately 100 grams was taken from the tip of each split spoon sample for laboratory determination of the soil moisture content. Soil moisture samples were placed in air tight tins immediately after they were taken from the split spoon samples. The moisture tin (sample) numbers were recorded on the field borehole logs. The samples were temporarily stored in the field and shipped in batches to the GLAL office for transfer to a commercial laboratory.

Rotary drilling. Rotary drilling techniques were occas-

ionally used to penetrate difficult soils that could not readily be drilled with conventional hollow stem auger drilling methods. These techniques were also used where granular soils, acting under hydraulic pressures, were forced up inside the hollow stem augers. This condition prevented the split tube and split spoon samplers from passing through the plugged portions of the hollow stem augers. Clean water or a water/bentonite mixture was circulated through a rotating tricone drill bit to clean out the material in the hollow stem augers. Rotary drilling was also used to drill through gravelly or bouldery soils such as those encountered at depth at Site LF-4N, Borehole 4, and at Site LF-2N, Borehole 1.

8.7.3.3 Bedrock sampling

Boreholes were generally completed into bedrock except in a few cases where difficult drilling conditions were encountered and the borehole was terminated before reaching bedrock.

The bedrock contact was often obscured as a result of weathering, particularly in shale. Under conditions of extreme weathering, shale was occasionally retrieved within the split tube and split spoon samplers. For example, a nearly complete 1.5 m core of weathered bedrock was obtained in the split tube sampler in Borehole 5 at Site PI-13N.

Diamond drill coring. Most bedrock samples were obtained using a diamond drill bit and NX size core barrel. Rock core samples generally measured about 53 mm (2.1 inches) in diameter and up to 3 m (10 ft.) in length. The diamond drill bit and core barrel were positioned on the bedrock

surface from inside the hollow stem augers. A rock core was obtained by the cutting action of the rotating drill bit. Clean water was circulated in the borehole to remove cuttings from around the drill bit. The water used in this operation was field checked with a Hach Kit for chlorides and sulphates to ensure compatibility with grouting materials used for borehole abandonment. The amount of water used was recorded on the field logs.

Bedrock coring was terminated when a sufficient length of sample was retrieved to prove-out the bedrock contact. The bedrock core recovered varied in length from about 1.5 m to 3 m (5-10 ft.) between borehole locations.

8.7.3.4 Sample description and storage

Soil and rock samples, taken from the boreholes, were described in detail in the field and photographed. Sample descriptions were recorded on the Field Borehole Log forms. These logs, together with the sample photos, form a permanent record of the sampling procedures.

The tube samples were transferred directly from the sampler into PVC tubular piping which was cut in half. The PVC pipe measures 89 mm (3.5 in.) inside diameter by 1.5 m (5 ft.) long. One 'side' of the sample was scraped clean along its length with a knife or spatula to facilitate sample description. Individuals and local interest groups were allowed to view the samples and make their own field notes of the samples. Soil scrapings were given to those interest groups that requested them or else were discarded. Soil samples were sealed in the PVC tubes by covering the

ends with plastic caps and taping the entire tube along the seams. Sample labels were affixed to each PVC tube.

The samples were stored temporarily in a field van until a sufficient number of samples were obtained for transport to permanent storage facilities in Toronto at the Ontario Geological Survey. Each shipment of samples were itemized on a Sample Packing list. The contents of each shipment were also recorded on a Chain of Custody Record which showed the times and dates of sample transfer as well as the individuals involved in handling the samples.

Split spoon soil samples taken during the project were described in the field and soil moisture (moisture tin) samples taken from the base of the split spoon sampler were submitted to a laboratory for analysis. The moisture tin number was recorded on the Field Borehole Log and on the Sample Packing List. In cases where a split spoon sample was taken in place of the larger split tube samples, they were stored in labelled plastic bags and retained with the other samples. The top of each bedrock core segment was marked on both the core boxes and on the rock core itself with a felt marker.

The soil and rock samples were re-examined by a senior GLAL geologist at the permanent storage area at the Ontario Geological Survey. The field descriptions were combined with the more detailed geologic log prepared by the senior geologist to compile a final borehole log. All soil samples were resealed after examination.

8.7.4 BOREHOLE ABANDONMENT

Boreholes were generally terminated after pentrating the bedrock or when difficult conditions prevented further drilling. An exception to this occurred at Site LF-1E, Borehole 3, where a gas pocket was encountered at a depth of about 17.8 m (58 ft.) in the drift. The borehole was terminated at this depth and sealed as soon as the gas pressure subsided sufficiently to allow grouting.

8.7.4.1 Grouting

On completion of each borehole all sampling equipment and temporary casing were removed from the borehole. Each borehole was then filled to the surface with a cement/ bentonite slurry. This was accomplished by injecting grout through the hollow stem augers as they were slowly withdrawn from the hole as shown in Figure 12. Specifications of the slurry mix, as set out in the Drilling and Sampling Protocol Document (GLAL 1984a) were altered slightly to accommodate site conditions. The actual grout slurry mix is compared on a percent weight basis to the specified grout slurry mix below:

Specified Grout Slurry	Actual Grout Slurry
1.2% Bentonite	2-3% Bentonite
6.0% Hydrated Lime (optional)	
59.6% Cement (Portland Type 10)	40-60% Cement (Portland Type 10)
33.2% Water	37-58% Water

The increased amount of bentonite provides a more effective seal in water bearing formations. The bentonite also acts as a 'plasticizing' agent and eliminated the need

Grouting Of Borehole

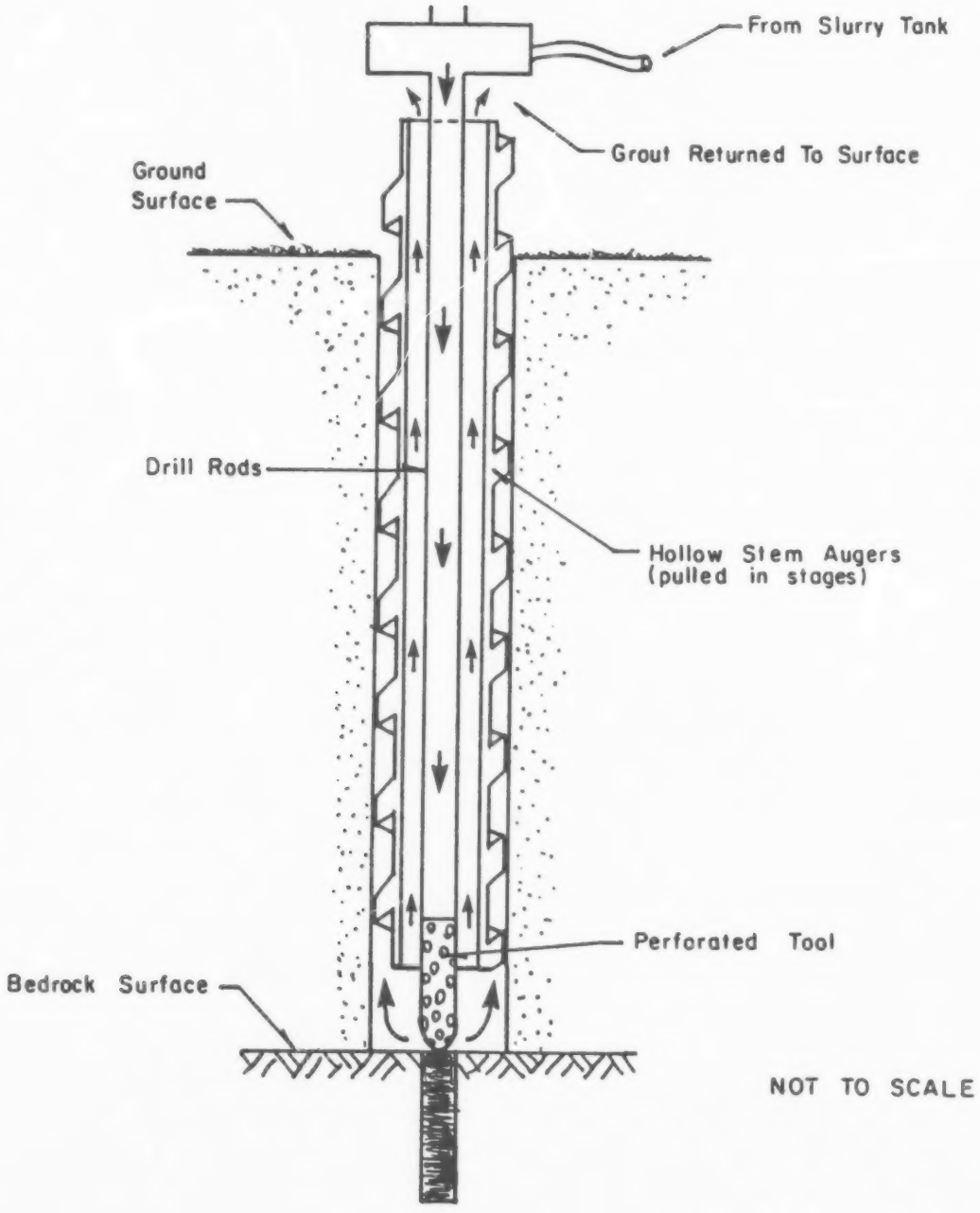

Figure 12

to add hydrated lime to the grout slurry mix. A cement mix containing slightly less than the amount of cement specified in the protocol was found to be adequate. A small sample of grout slurry was taken from each hole to confirm the setting characteristics of the mix.

The water used in the grout slurry was obtained locally and was tested wth a Hach Kit for sulphate and chloride content. Details of each grout mix were recorded on the Borehole Plugging Plan/Record for each borehole.

The grout was allowed to set overnight and generally settled to within 1 to 3 m (3-10 ft.) of ground surface. The hole was subsequently backfilled to grade with soil to avoid interference with surface activities such as ploughing or maintenance along road allowances. All boreholes from this drilling program were successfully grouted.

8.7.4.2 Site cleanup

Efforts were made to restore each drill location to predrilling conditions. The ground was levelled to grade and holes or ruts made by drilling equipment were filled with soil and in some cases resodded. While attempts were made to minimize damage, this was not always possible and compensation was provided in some cases. Photographs were taken of each drill location both before and after the drilling operations and after site cleanup.

A
B
B
TRAFALGAR ROAD
BRITANNIA ROAD
DERRY ROAD
SIXTH LINE
FIFTH LINE
OUTER LINE
EIGHTH LINE
DRUMQUIN
LOT 9 CON 5
LOT 7 CON 6
LOT 5 CON 7
LOT 4 CON 8
LOT 3 CON 8
LOT 9 CON 4
LOT 5 CON 9
LOT 1 CON 1
2658 (188)
2767 (184)
2657 (188)
2629 (182)
2605 (188)
3673 (188)
2628 (179)
4139 (185)
2627 (188)
3738 (191)
6869 (192)
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2650 (187)
2647 (188)
2546 (193)
NB-OW1 (192)
2589 (194)
NB-OW2 (191)
GL3 (191)
NB-OW4 (193)
NB-OW3 (191)
GL2 (191)
GL6 (189)
GL4 (192)
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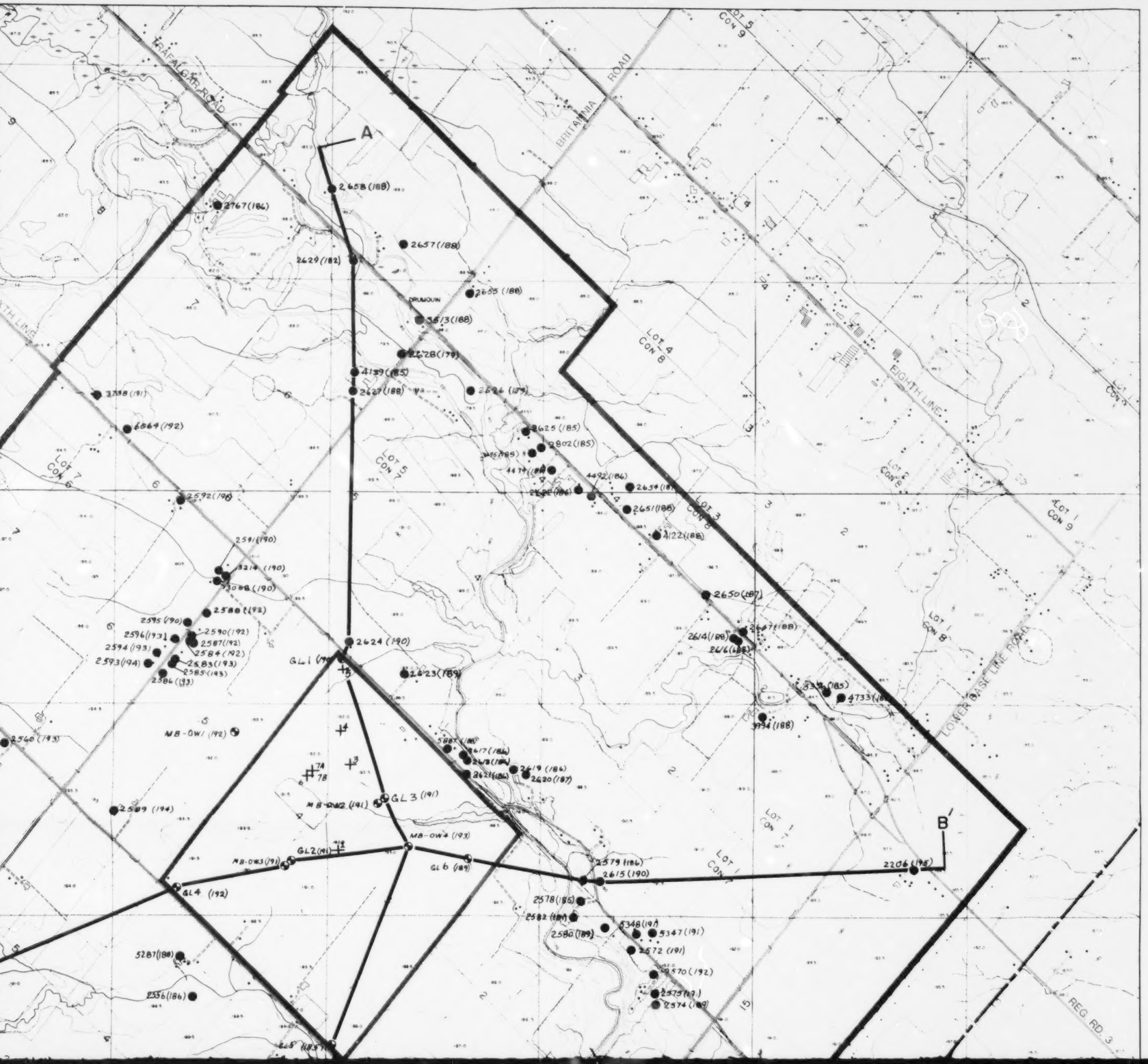


OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

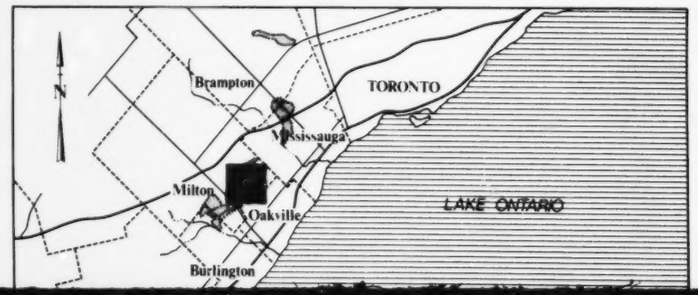
- ●5347(191) WATER WELL LOCATION, WELL No. WELL ELEVATION (METERS)
- GL- GARTNER LEE ASSOCIATES LIMITED BOREHOLE
- MB- MORRISON BEATTY BOREHOLE (OBSERVATION WELL)
- A A' GEOLOGIC CROSS-SECTION
- + 3 FIELD STATION

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map:

PI-13 North

Lots 3 and 4; Concession VI; Town of Milton, formerly the Township of Trafalgar



FOURTH LINE

THIRD LINE

EAST SIXTEEN MILE CREEK

BOYNE

ENDRICK

GL1 (191)

GL2 (191)

GL3 (191)

GL4 (192)

GL5 (185)

GL6 (189)

MB-OW1 (192)

MB-OW2 (191)

MB-OW3 (191)

MB-OW4 (193)

LOT 7 CON 4

LOT 6 CON 3

LOT 5 CON 3

LOT 4 CON 3

LOT 1 CON 4

LOT 1 CON 5

LOT 1 CON 6

LOT 1 CON 7

LOT 16 CON 2N

LOT 20 CON 2N

HWY 25

Contour Interval

1:10 000 base mapping

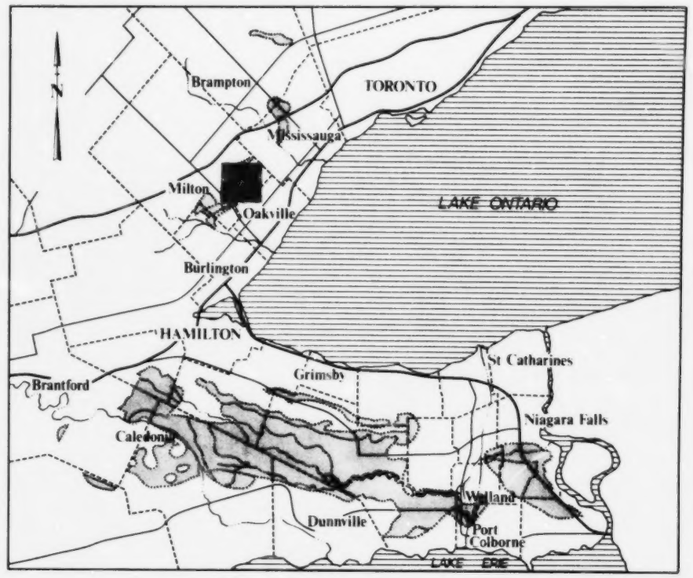
Ministry of Natural Reso

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map:

PI-13 North

Lots 3 and 4; Concession VI; Town of Milton, formerly the Township of Trafalgar



1000 feet 0 1000
500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Well and Borehole Locations

September 1985 **FIGURE 4**

Contour Interval in Metres

1:10000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

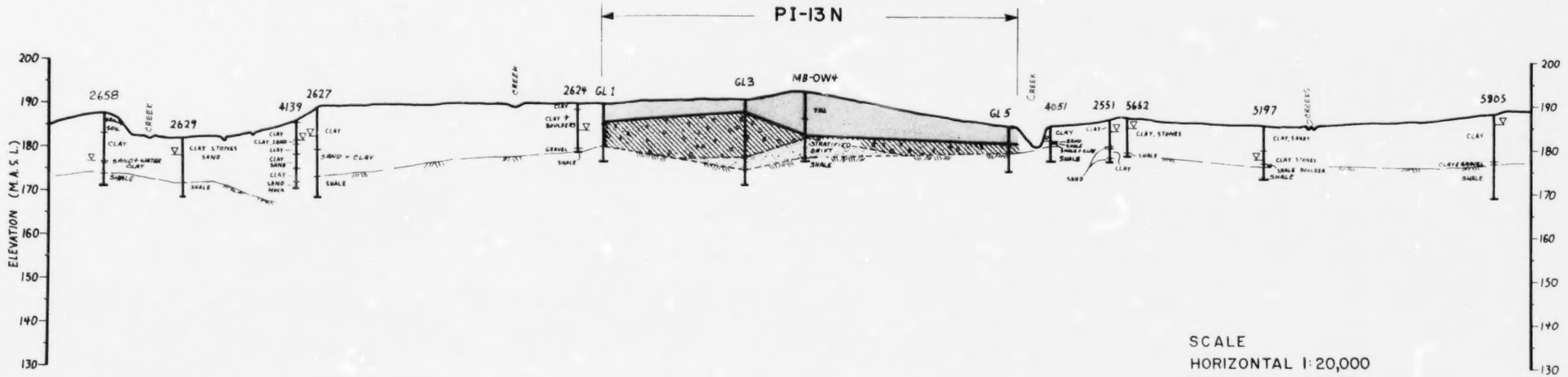
North

A

Looking East

South

A'



(Geologic conditions between boreholes may vary from interpretations shown)

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

Site PI-13 N
CROSS-SECTION A-A'
Figure 5

LEGEND

GL 3 Gartner Lee Associates Limited Borehole (1984)
MB-OW4 Morrison Beatty Limited Borehole (1984)
2579 Water Well With Ministry of Environment Number
∇ Static Water Level in Well at Time of Construction
m a.s.l. Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- CLAYEY SILT TILL (Halton Till)
- INTERBEDDED SANDY SILT TILL AND SAND
- SAND
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

NOTES: Consult Water Well Record Summary and Borehole Logs in Sections 8.1 and 8.3 for detailed descriptions.

Elevations are approximate
Cross-Section Located in Figure 4

To accompany Phase 4A Technical Appendix
(Geologic Hydrogeologic and Geotechnical Considerations)

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

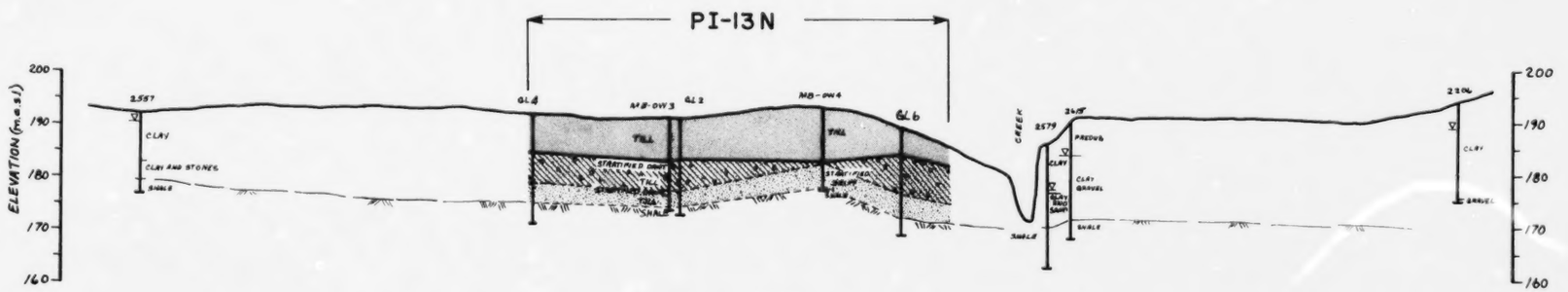
West

B

Looking North

East

B'



(Geologic conditions between boreholes may vary from interpretations shown)

SCALE
HORIZONTAL 1:20,000
VERTICAL 1:1,000
Vertical Exaggeration, 20x

Site PI-13N
CROSS-SECTION B-B'
Figure 6

LEGEND

GL 3 Gartner Lee Associates Limited Borehole (1984)
MB-OW4 Morrison Beatty Limited Borehole (1984)
2579 Water Well With Ministry of Environment Number
∇ Static Water Level in Well at Time of Construction
m a.s.l. Metres above sea level

INTERPRETIVE OVERBURDEN LEGEND
GLAL BOREHOLE LOGS

- CLAYEY SILT TILL (Halton Till)
- INTERBEDDED SANDY SILT TILL AND SAND
- SAND
- BEDROCK
- Preliminary Interpretive Geologic Boundary
- Limit of Confining Layer

NOTES: Consult Water Well Record Summary and Borehole Logs in Sections 8.1 and 8.3 for detailed descriptions.

Elevations are approximate
Cross-Section Located in Figure 4

To accompany Phase 4A Technical Appendix
(Geologic Hydrogeologic and Geotechnical Considerations)

OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

CREIGHTON ROAD
SIXTH LINE
FOURTH LINE
BRITANNIA ROAD
LOT 9 CON 5
LOT 7 CON 6
LOT 5 CON 7
LOT 4 CON 8
LOT 3 CON 9
LOT 9 CON 4
LOT 7 CON 5
LOT 5 CON 6
LOT 4 CON 7
LOT 3 CON 8
LOT 1 CON 7
OMAGH
CARNOLIN
MEADOWVALE
GL 1
GL 2
GL 3
GL 4
GL 5
GL 6
2658 10.7
2767 9.8
2657 2.7
2625 10.4
2685 17.7
3738 9.8
6064 4.6
2624 11.0
2625 6.4
2679 6.3
2654 9.7
2651 10.4
4122 0.5
2650 7.9
2624 10.1
2623 8.5
2560 15.2
2589 11.9
2580 4.9
2582 9.8
2570 4.6
2574 12.2
4733 9.8
2304 8.5

OWMC **Ontario Waste Management Corporation**

Consultant: Gartner Lee Associates Limited

Legend:

- GL — GARTNER LEE ASSOCIATES LIMITED BOREHOLE
- MB– — MORRISON BEATTY LIMITED BOREHOLE
- ● — WATER WELL WITH MINISTRY OF ENVIRONMENT NUMBER
- 24.1 — THICKNESS OF CONFINING LAYER IN METRES
- XX — BEDROCK EXPOSURE IN STREAM CUT

NOTES: THE CONFINING LAYER SHOWN INCLUDES THE WEATHERED & FRACTURED ZONE

THE CONFINING LAYER THICKNESS VALUES FROM M.O.E. WELL RECORDS SHOULD BE REGARDED AS APPROXIMATE

DEPTH WHICH IS EXPOSED ALONG EAST SIXTEEN MILE CREEK IS ESTIMATED FROM

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map: **PI-13 North**

Lots 3 and 4; Concession VI; Town of Milton, formerly the Township of Trafalgar

LOT 7 CON 4

LOT 6 CON 4

LOT 5 CON 4

LOT 4 CON 3

LOT 3 CON 3

LOT 2 CON 3

LOT 1 CON 4

LOT 21 CON 2N

LOT 20 CON 2N

EAST BOUNDARY OF THE TOWNSHIP OF GLENORCHY

BOYNE

GLENORCHY

Contour Interval

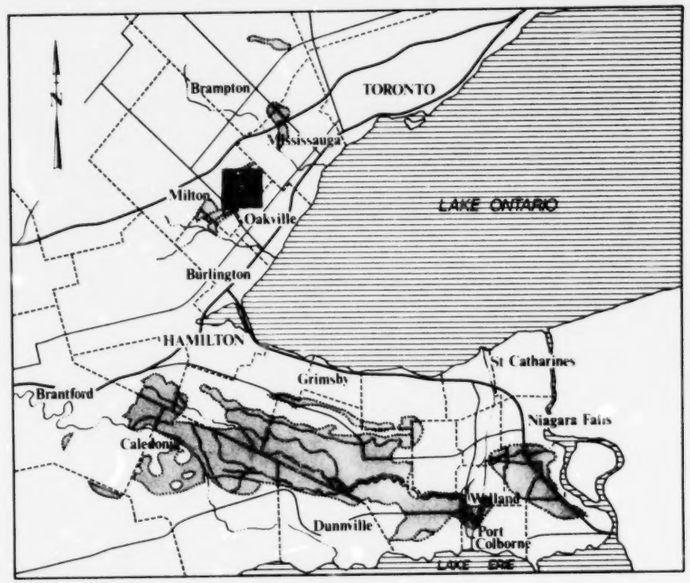
1:10000 base mapping
Ministry of Natural Re

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map:

PI-13 North

Lots 3 and 4; Concession VI; Town of Milton, formerly the Township of Trafalgar



1000 feet 0 1000
500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Confining Layer Thickness

September 1985 **FIGURE 7**

Contour Interval in Metres

1:10000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984

TRAFALGAR ROAD
DERRY ROAD
SIXTH LINE
BRITANNIA ROAD
EIGHTH LINE
FIFTH LINE
FOURTH LINE
OMAGH
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LOT 7 CON 6
LOT 4 CON 8
LOT 3 CON 8
LOT 7 CON 4
LOT 7 CON 7
LOT 1 CON 7
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OWMC Ontario Waste Management Corporation

Consultant: Gartner Lee Associates Limited

Legend:

- DRILLED WELL COMPLETED IN OVERBURDEN, BEDROCK
- DUG OR BORED WELL COMPLETED IN OVERBURDEN, BEDROCK
- FLOWING CONDITIONS
- UNUSED, ABANDONED WELL
- DUGOUT OR POND
- CISTERN
- ADDITIONAL FIELD INFORMATION

NOTES: Details for wells with Ministry of Environment numbers (3 and 4 digits) are provided in the Summary of Water Well Data (Table 4, Section 4.1). Other numbers accompany wells, cisterns, dugouts or ponds, and locations where 'additional field information' was gathered. Details for these are provided in the Summary of Site Interview Data (Table 5, Section 4.2)

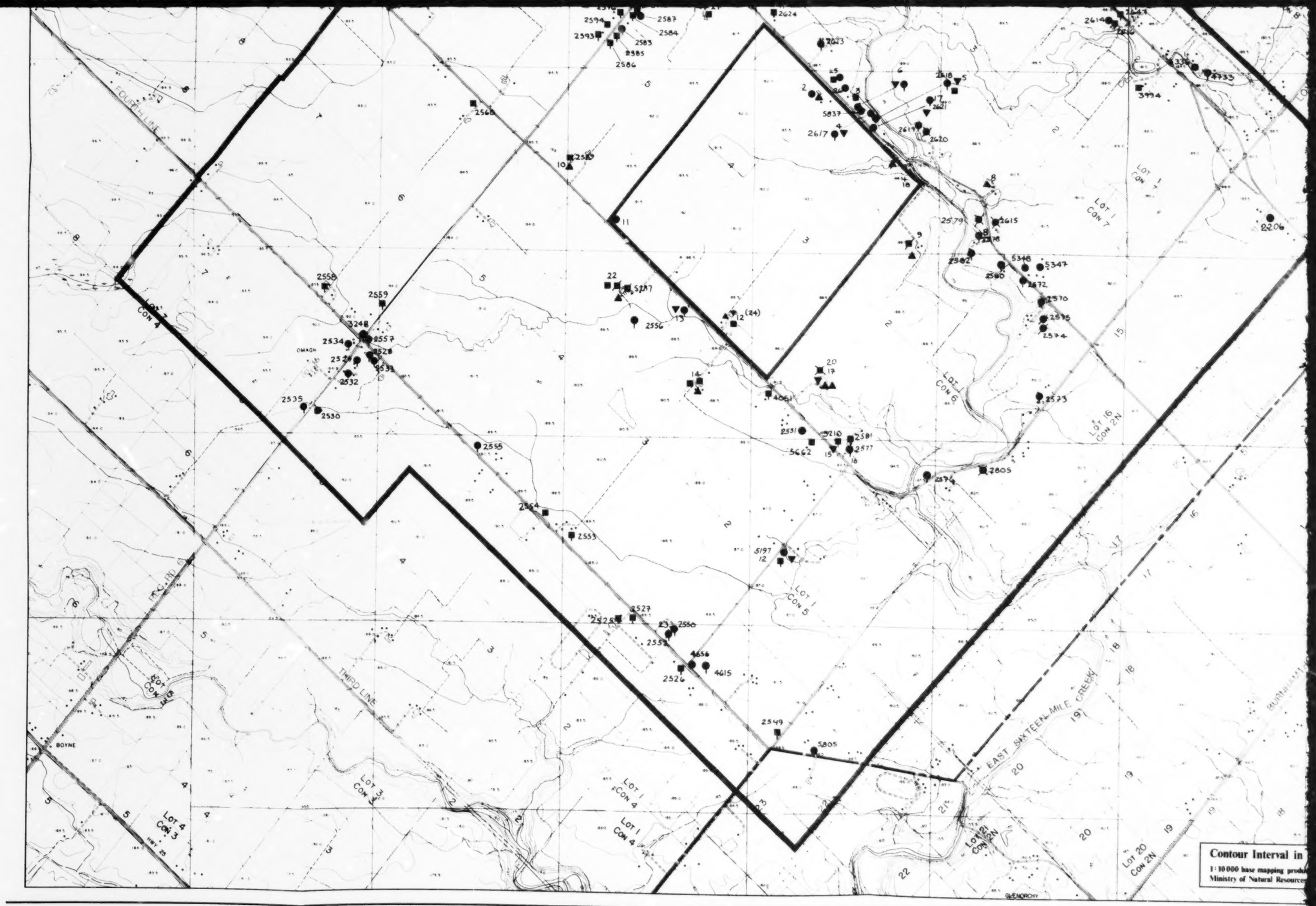
Phase 3B Acquisition Boundary

Site Vicinity Study Area Boundary

Key Map:

PI-13 North

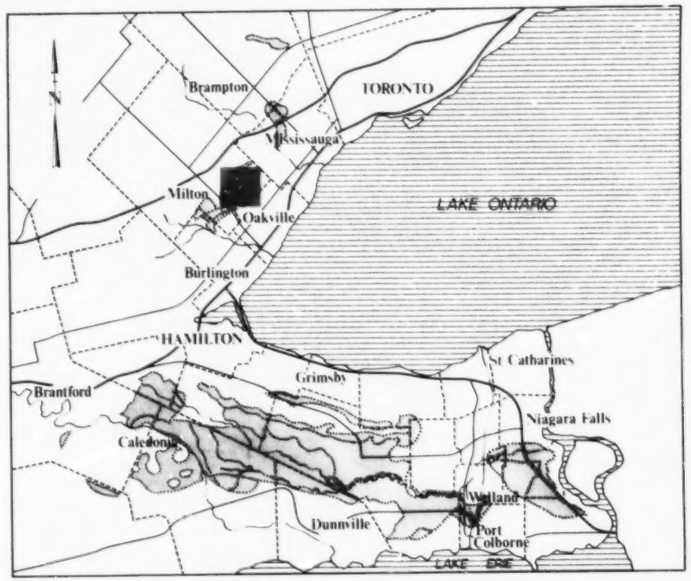
Lots 3 and 4; Concession VI; Town of Milton, formerly the Township of Trafalgar


FOURTH LINE
THIRD LINE
LOT 1 CON 7
LOT 1 CON 6
LOT 16 CON 2N
LOT 20 CON 2N
LOT 1 CON 5
LOT 1 CON 4
LOT 3 CON 3
LOT 4 CON 3
EAST SIXTEEN MILE CREEK
BOYNE
GLENORCHY
OMAGH
HWY 25
Contour Interval in
1:10000 base mapping produ
Ministry of Natural Resource

Phase 3B Acquisition Boundary — Site Vicinity Study Area Boundary

Key Map: **PI-13 North**

Lots 3 and 4; Concession VI; Town of Milton, formerly the Township of Trafalgar



1000 feet 0 1000
500 metres 0 500

GEOLOGIC, HYDROGEOLOGIC, AND GEOTECHNICAL CONSIDERATIONS PHASE 4A

Ground Water Use

September 1985 **FIGURE 8**

Contour Interval in Metres

1:10000 base mapping produced by Surveys and Mapping Branch, Ministry of Natural Resources between 1976 and 1984